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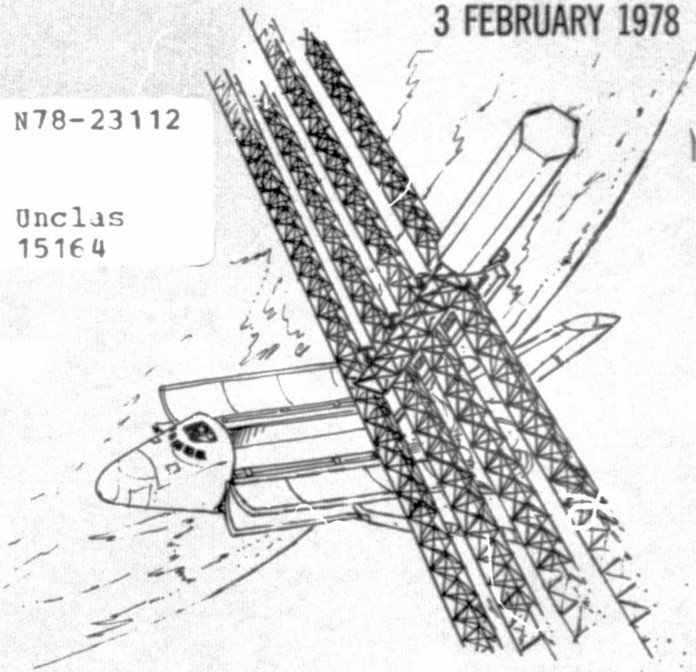

SPACE CONSTRUCTION AUTOMATED FABRICATION EXPERIMENT DEFINITION STUDY (SCAFEDS)

PART II FINAL BRIEFING

CONTRACT NO. NAS9-15310
DRL NO. T-1346
DRD NO. MA-665T
LINE ITEM NO. 4

GENERAL DYNAMICS
Convair Division

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Submitted to
National Aeronautics and Space Administration
LYNDON BAINES JOHNSON SPACE CENTER
Houston, Texas

Prepared by
CONVAIR DIVISION OF GENERAL DYNAMICS
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The Part II Final Review is the fourth and last review scheduled for the SCAFED Study. The majority of the presentation addresses the status of those study tasks undertaken since the Part II Midterm Review, followed by a summary presenting the principal study conclusions as well as recommendations for future activity.

A Study Overview/Summary of earlier effort is also included for those unfamiliar with the objectives, baseline system concept, and study approach.

PART II FINAL REVIEW

INTRODUCTION

- Overview

FLIGHT EXPERIMENT INTEGRATION

- Requirements & operations
- Tests & experiments
- EVA/IVA
- Future applications

SYSTEM DESIGN & ANALYSIS

- Fabrication systems
- On-orbit environment & behavior

PROGRAMMATICS

- Development plan & cost

STUDY SUMMARY

- Conclusions
- Recommendations

01028082J0327

The top-level objectives of this definition study are presented on the accompanying chart. The corresponding objectives for downstream program phases consist of the development and flight demonstration of the techniques, processes, and equipment identified and defined during this study.

STUDY OBJECTIVES

- **DEFINE:**

  The techniques, processes, and equipment required
  for automatic fabrication and assembly
  of structural elements in space
  using Shuttle as a launch vehicle and construction base

- **IDENTIFY AND DEFINE:**

  Additional construction/systems/operational
  techniques, processes, and equipment
  which can be developed/demonstrated in the same program
  to provide further risk reduction benefits
  to future large space systems.

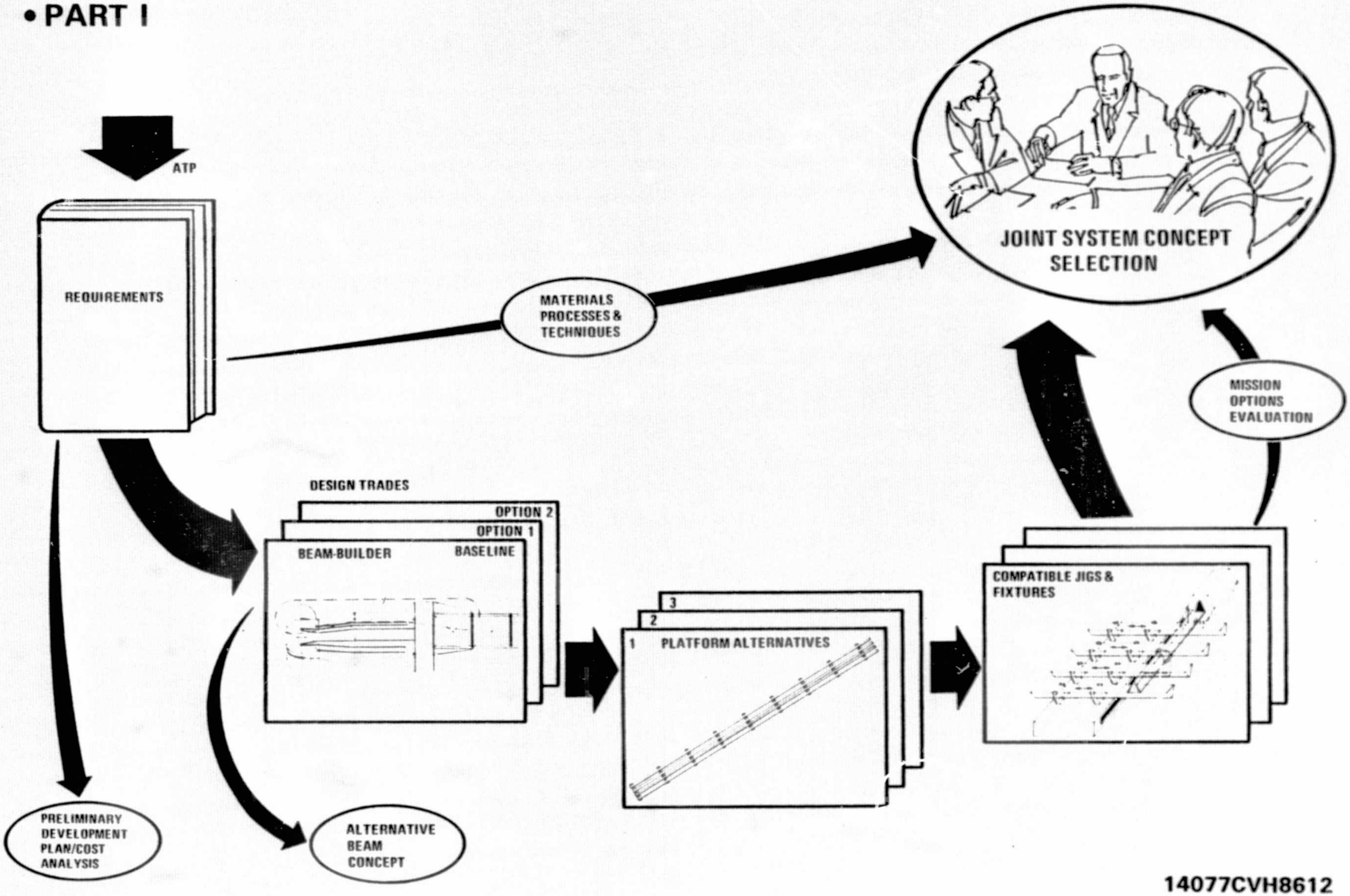
Study activities were divided into two parts, with the Part I task flow shown on the facing chart.

Part I exhibited a predominately linear flow proceeding from requirements analysis through a series of converging design trades addressing beam-builder options, structural platform alternatives, and associated jigs and fixtures. Baseline concepts for the platform structure and beam-builder were used as reference configurations in these trades. Materials, processes, and techniques were evaluated in parallel supporting tasks. These efforts, plus an evaluation of mission options led to a Convair/NASA joint selection of a preferred total system concept at the end of Part I.

Two additional tasks were also accomplished in Part I. A preliminary development plan and cost analysis for the total SCAFE Program was submitted to support long range NASA/JSC program planning, and preliminary evaluation of an alternative geodetic beam concept, with potential application to future large space systems, was conducted.

STUDY APPROACH

• PART I



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In Part II of the SCAFED Study we have prepared conceptual designs of the selected total system concept. This effort led to definition of platform performance verification tests and associated subsystem equipment. Coordinated stress, dynamics, stability and control, thermal, and mass properties analyses supported both efforts.

A parallel task series assessed STS compatibility, analyzed mission options, and evaluated the role of EVA in the experiment. The study effort has concluded with definition of development program plans and associated cost analyses, which update/amplify the Part I preliminary data by incorporating study-generated data.

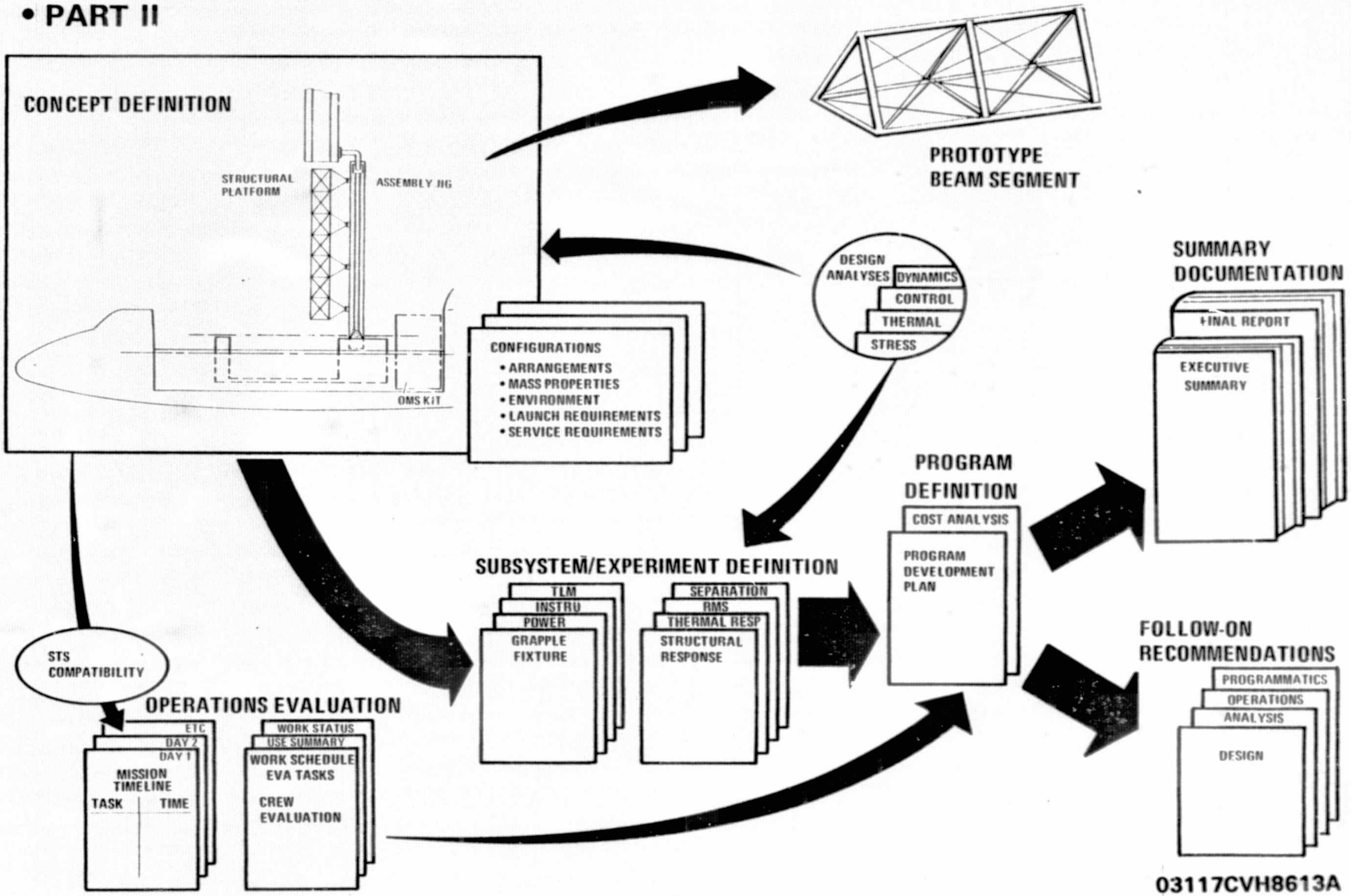
The requirements document is also being updated and is expected to serve as an initial version of the SCAFE Program System Specification.

In addition to engineering effort, the study also includes one manufacturing task. A full-scale prototype beam segment, reflecting the selected structural concept, has been designed and fabrication is in progress.

Study output includes both summary documentation and recommendations for follow-on activities.

STUDY APPROACH

• **PART II**



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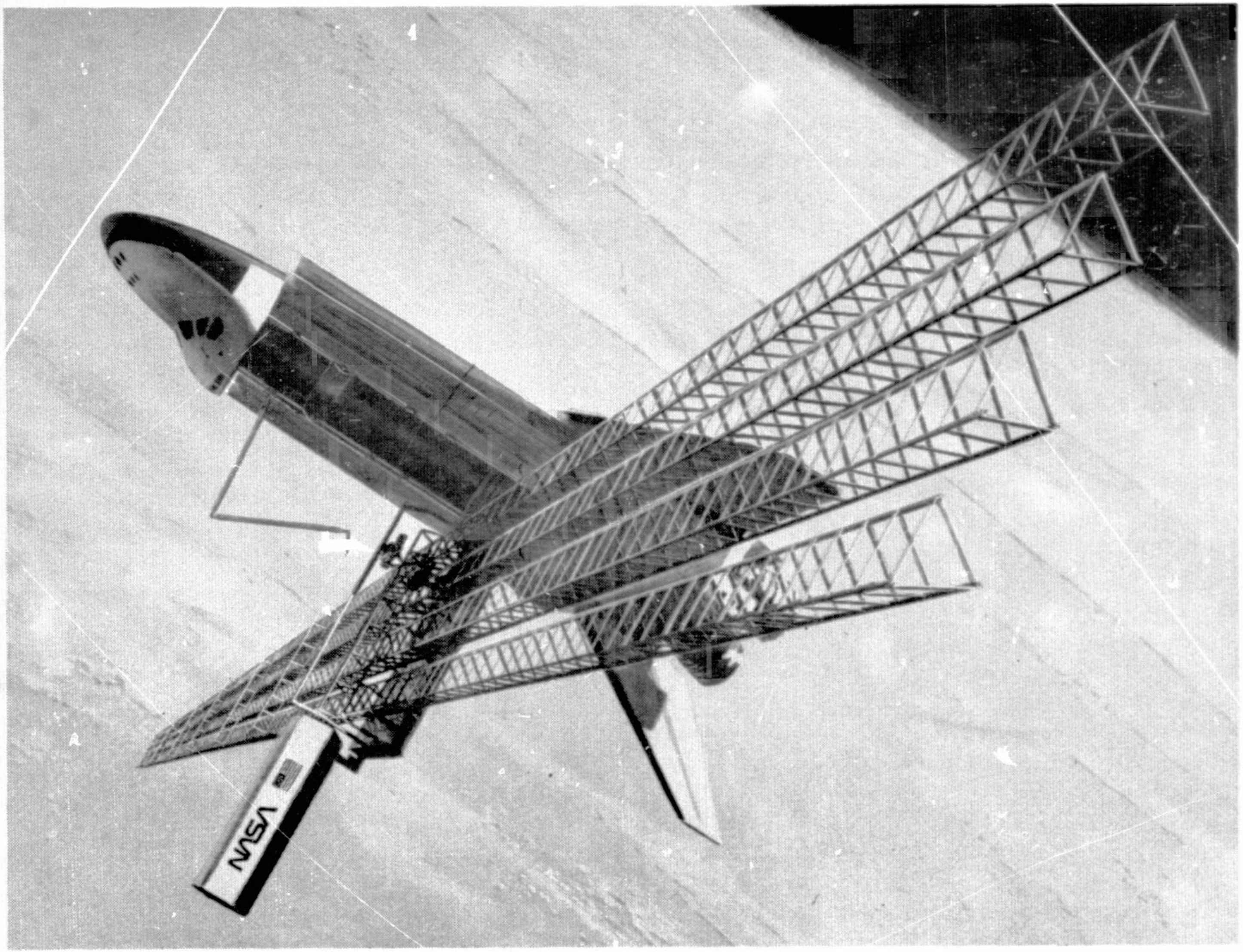
The baseline SCAFE system concept is shown in the facing illustration. In mid-1982, fabrication/assembly systems and prepackaged raw materials are delivered by Shuttle to a 300 nautical mile (556 Km) circular orbit.

Upon system deployment from the stowed position, a beam-builder, moving to successive positions along a Shuttle-attached assembly jig, automatically fabricates four triangular beams, each 200 meters long. Retention of the completed beams is provided by the assembly jig.

The beam-builder then moves to the position shown and fabricates the first of nine shorter, but otherwise identical, cross-beams. After cross-beam attachment, the partially completed assembly is automatically transported across the face of the assembly jig to the next cross-beam location, where another cross-beam is fabricated and installed. This process repeats until the "ladder" platform assembly is complete. During this process an opportunity to develop/evaluate EVA is provided by the difficult-to-automate task of sensor/equipment attachment, as shown.

Upon platform assembly completion, both structural and thermal response tests are conducted and RMS/platform release/recapture techniques are developed. The seven-day mission cycle concludes with EVA demonstration of unscheduled maintenance and repair activities followed by platform separation and Shuttle return.

BASELINE SYSTEM CONCEPT



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PART II FINAL REVIEW

INTRODUCTION

Overview

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PROGRAMMATICS

Development plan & cost

STUDY SUMMARY

Conclusions
Recommendations

01028082J0328

The first objective on the chart states the overall program objective. The second one denotes the basic fabrication and construction techniques required to be developed and proven in the on orbit experiment operation. Included are the functions to be performed by the astronauts. Work accomplished during the studies showed that man would not be efficiently used performing construction tasks; these were best done automatically. Man can be used more efficiently controlling and monitoring the construction operation and installing the equipment and instrumentation. Also he can be used efficiently making required repairs to the platform and the beam building machinery.

SCAFE OBJECTIVES

Develop & demonstrate techniques, processes & equipment required for automated construction, systems integration, and operation of large space systems

Develop & demonstrate:

- Construction material verification
- Basic truss element fabrication
  - Joints & joining
  - Material forming
- Multiple truss element assembly
- Large structure handling
- Equipment/component installation
- Manned orbital operations
  - IVA
    - Construction monitor/control
    - Vehicle stability & control
  - EVA
    - Equipment handling/installation
    - Repair demonstration

The following guidelines were established by the NASA to help define the baseline mission. The study has shown that all the SCAFE objectives can be met on a single mission. A revisit mission is desirable to use the platform and its resources to support additional applications experiments.

SCAFE MISSION REQUIREMENTS

COMPATIBLE WITH STS

- CG constraints
- Payload bay envelope & accommodations
- Performance
- Launch turnaround

SINGLE MISSION – MID 1982

- Construction & operation of platform
- Dynamic & thermal response experiments
- Separation & recapture demonstration – prelude to optional revisit mission
- Appropriate applications experiments after separation
- EVA activity provided by nominal four-person crew
- Experiment equipment & support subsystems

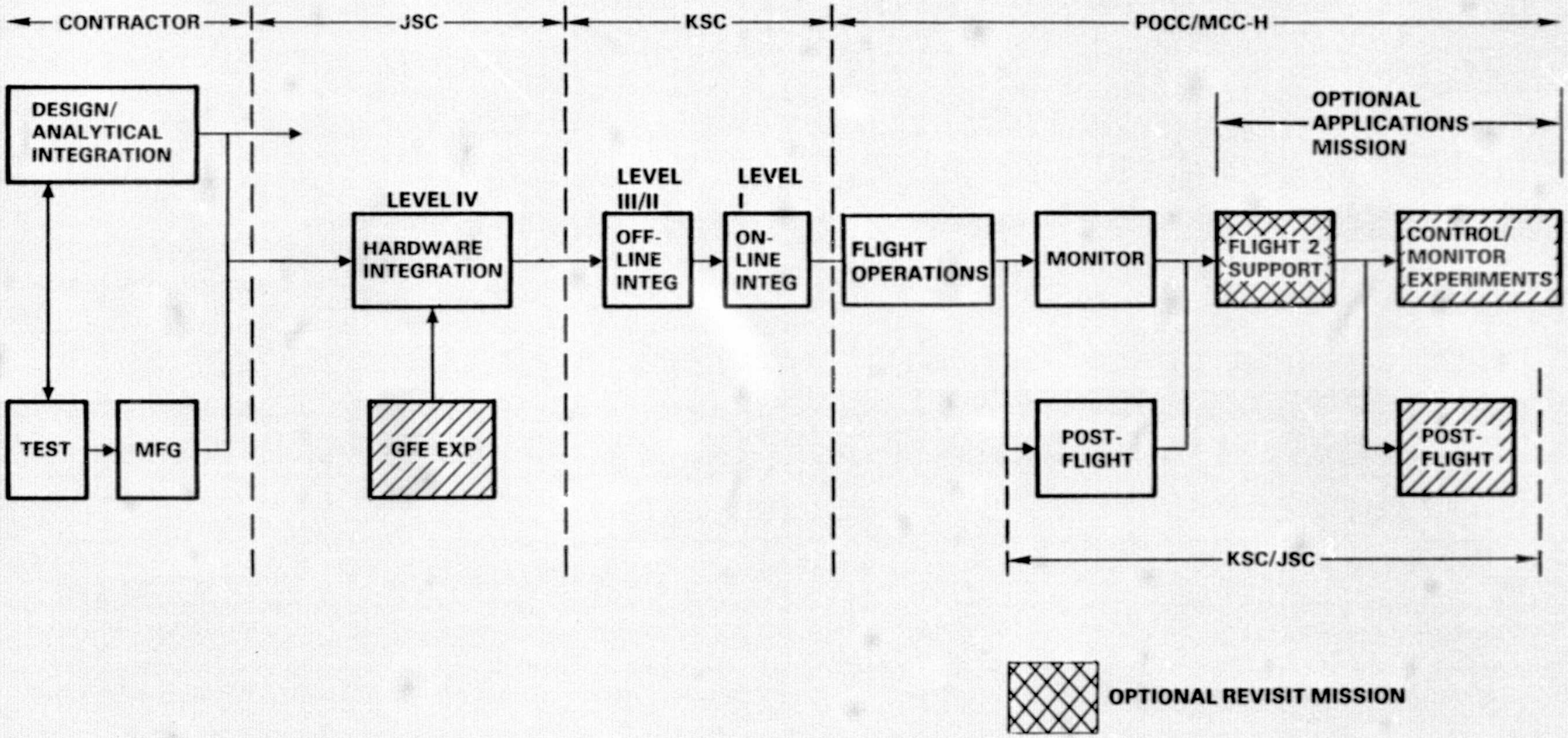
REVISIT MISSION (OPTIONAL) WITHIN THREE MONTHS

This chart depicts the total top level operational flow for the SCAFE program. The contractor will design, manufacture and test the structural experiment equipment along with the structural test instrumentation. This equipment will be integrated and checked out with the applications experiment equipment at JSC and then shipped to KSC for launch site operations and launch. During flight the orbiter crew initiates each operational or test phase and controls, orbiter maneuvers and the RMS. Executive control and monitor of the beam fabrication on-orbit operation is provided via the Orbiter RF command lines ground controllers at the Payload Operations Control Center (POCC) which is co-located with Mission Control Center-Houston (MCC-H). MCC-H provides orbiter and overall mission control.

All the SCAFE objectives are met with the first flight so the second flight is shown as an option to carry up additional applications experiments.

SCAFE PROGRAM TOP LEVEL ACTIVITIES

- PROGRAM ACTIVITIES FLOW



The preceding chart shows the top level operational flow for the SCAFE program and depicts the three major ground activities and locations where these are proposed to take place. Factory acceptance testing will take place at the contractor's facilities. Equipment integration, referred to as Level IV integration, of the structural experiment equipment and instrumentation, scientific experiment equipment, and supporting subsystems will take place at JSC. Launch site operations, including Levels III/II/I integration, will take place at KSC.

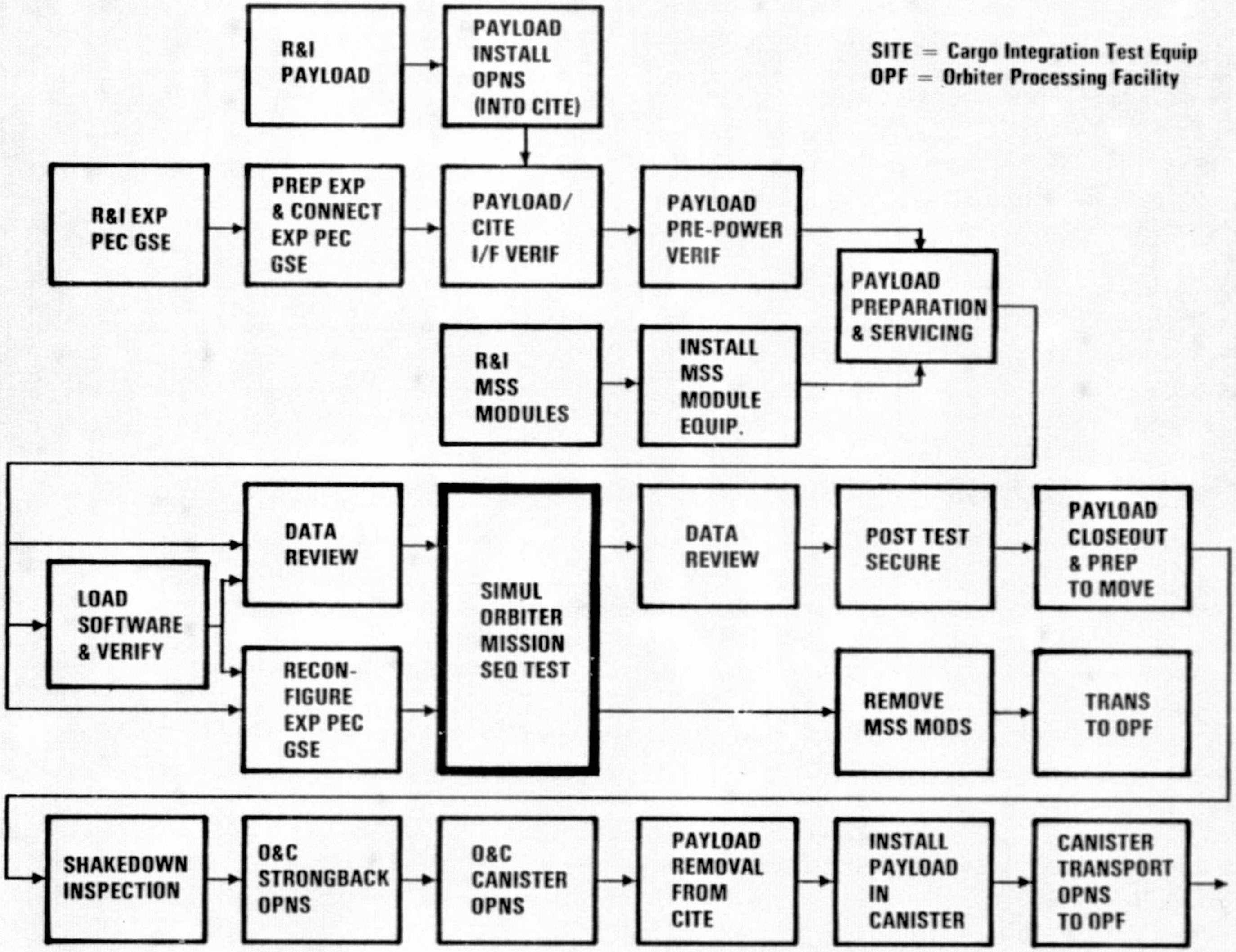
This chart as an example, shows the proposed flow which would take place for Level III/II integration at KSC in the Operations and Checkout Building. The payload equipment is installed in the Cargo Integration Test Equipment (CITE) test stand and serviced and prepared for operation. Power up tests are performed and the experiment flight software is loaded and verified. At this time the mission sequence simulation is performed. After the simulation the experiment equipment is reserviced for flight and moved to the Orbiter Processing Facility.

The SCAFE equipment is compatible with KSC cargo integration and checkout procedures.

GENERAL DYNAMICS
Convair Division

PRELIMINARY LEVEL III/II PAYLOAD INTEGRATION FLOW DIAGRAM
(Off-Line - Operations & Checkout Building

SITE = Cargo Integration Test Equip
OPF = Orbiter Processing Facility



SCAFE equipment compatible with KSC cargo integration & checkout procedures

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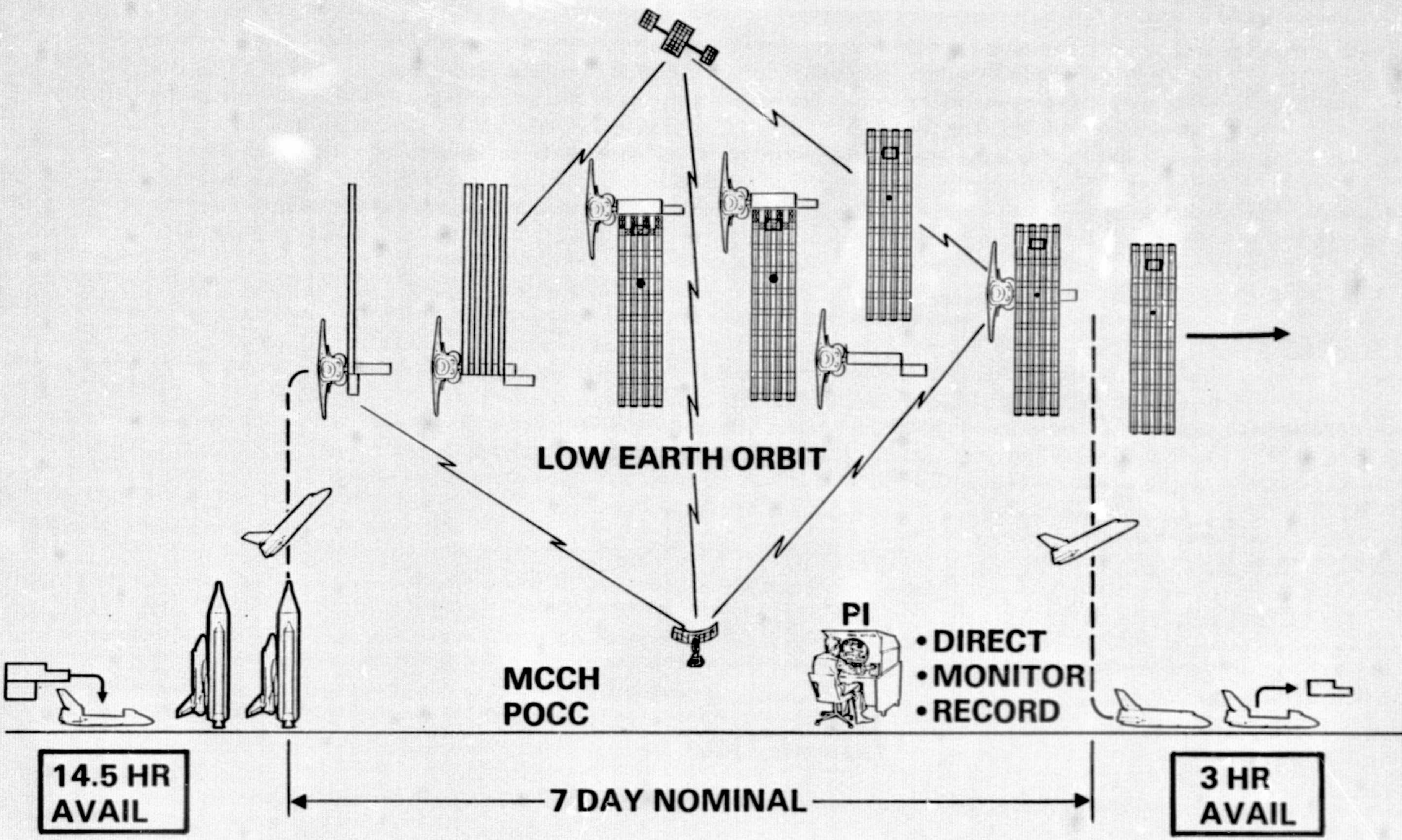
This chart indicates the flight profile for the Orbiter portion of the SCAFE to satisfy the objectives discussed previously. 14.5 hours are available for on-line integration with the orbiter before the mission. The SCAFE equipment will be installed with orbiter in the horizontal position in the Orbiter Processing Facility. It will not require special environmental monitoring or control during any ground operations phase or time critical prelaunch access at the pad. Payload handling in the vertical position is not planned; however, it is not precluded by the design.

During ascent (or re-entry) to the delivery orbit the SCAFE equipment is inactive - requiring only mechanical and caution and warning support from the orbiter. The nominal mission is seven days long. The orbiter crew initiates each operational or test phase and controls orbiter maneuvers and RMS operations. Before the start and during the initial phase of the beam building experiment, an EVA operation is performed to make sure the equipment is functioning properly.

During the beam building operation the equipment operates automatically under the control of the experiment computer. When the first beam is finished a dynamic response test will be conducted to determine its characteristics and data fed back to the ground to compare with the predicted behavior. This will help predict the characteristics and behavior of the completed platform. The remainder of the platform will be completed by the middle of the third day. During this time the crew monitor the operation at the aft flight deck and observe directly and with TV. During the afternoon of the third day, another EVA is performed to install the test instrumentation, the subsystems, and the free flight experiment equipment. On the fourth day the dynamic response and thermal deflection experiments will be checked out and performed. The morning of the fifth day the separation and recapture demonstration experiment will be conducted. The dynamic response and thermal deflection tests will resume on the afternoon of the fifth day.

On the sixth day another EVA operation will be performed to simulate repair which might occur on operational platforms. The seventh day will be used for releasing the platform ready to perform the free-flying scientific experiments (Geodynamics and Atmospheric Composition) and to continue the dynamic response and thermal deflection experiment, closeout activity and re-entry. Executive control and monitor of the beam fabrication on-orbit operation is provided via the orbiter RF command link ground controllers at the Payload Operations Control Center (POCC) which is co-located with Mission Control Center-Houston (MCC-H). MCC-H provides orbiter and overall mission control.

SCAFE FLIGHT PROFILE



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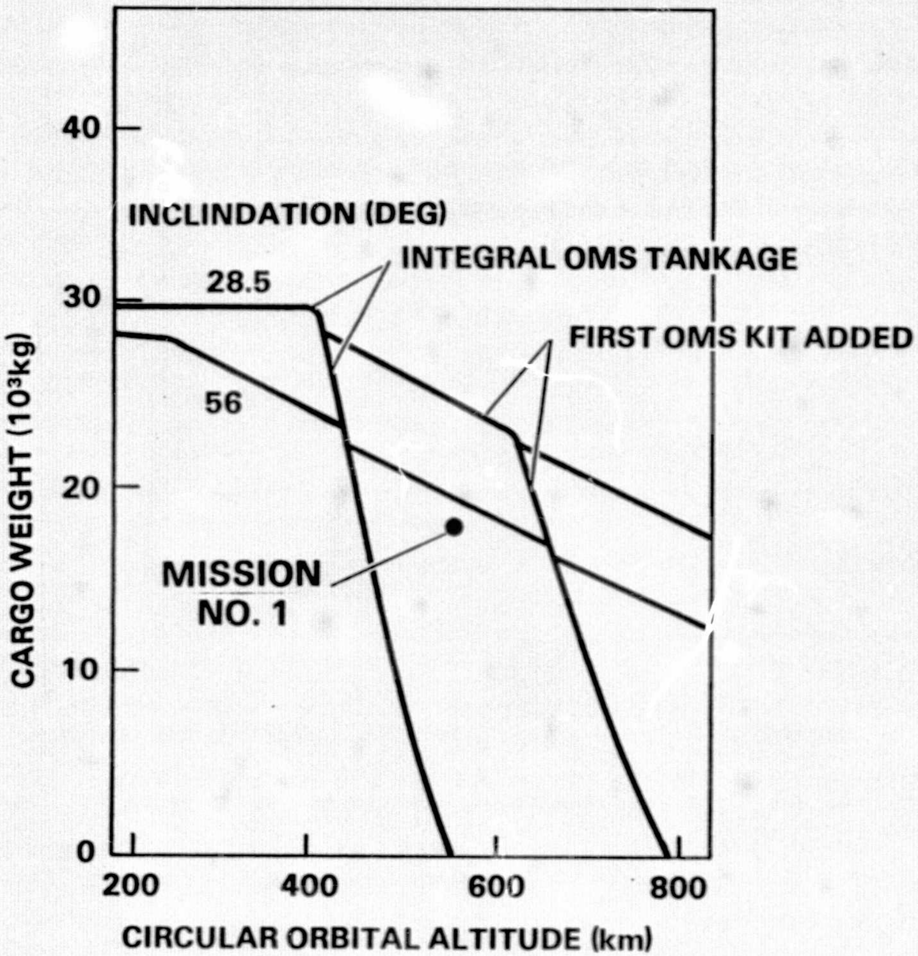
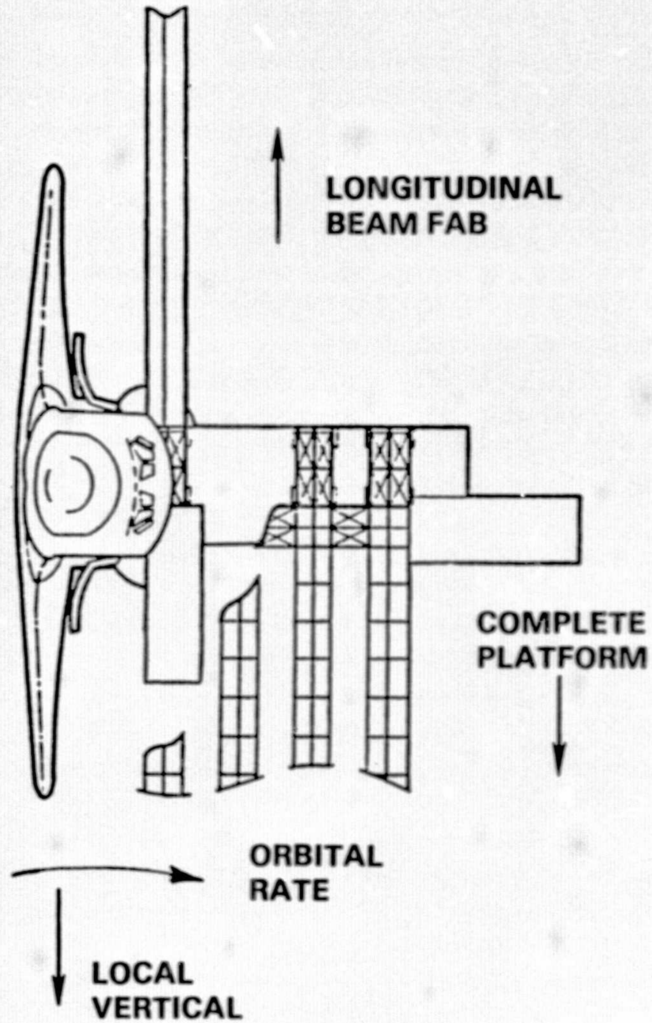
Analysis has shown that the experiment can be conducted in orbit inclinations from $28\frac{1}{2}$ to 57 degrees. However, $28\frac{1}{2}$ is the most acceptable because the payload capability is higher as shown on the chart. For orbital altitude, analysis shows that below approximately 555 KM the orbital lifetime of a representative platform drops off rather sharply. This would make it undesirable to carry out applications experiments after the first flight and preclude time for an optional revisit mission to carry out additional applications experiments. Altitudes above 550 KM at $28\frac{1}{2}$ degrees would require an OMS kit further reducing payload and volume available. Therefore, a 555 KM orbit altitude was chosen.

Early analysis selected a constant earth fixed orientation for SCAFE. However, within the earth-fixed family, several options exist for orientation of system coordinate axes with respect to both the earth and the orbit plane. The free-platform is stable if oriented in-plane with its long axis radial, and separation from the orbiter in that orientation is desirable. However, the final orientation selection required system mass properties and stability/control analyses plus consideration of several other factors including viewing/illumination, potential thermal constraints on either the Orbiter or the platform, and communication capability. These analyses are covered on other charts. The result of the combined evaluation was the selection of the reference orientation as shown as the preferred attitude for SCAFE fabrication, assembly, and test.

SCAFE MISSION CHARACTERISTICS



ORBITAL ALTITUDE AND INCLINATION



SELECTED FABRICATION ORIENTATION

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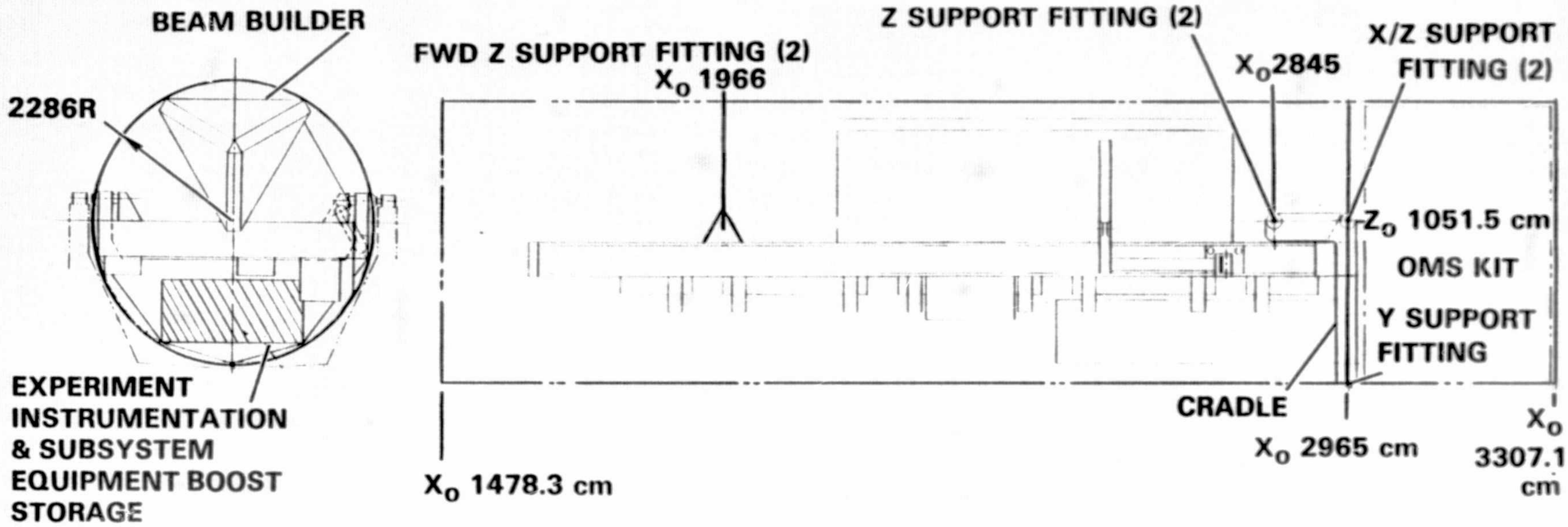
This chart indicates the SCAFE equipment stowed in the cargo bay for launch. The assembly jig is supported from a short cradle and a forward cargo bay mount. The beam builder is supported on the assembly jig and the supporting subsystem and experiment instrumentation packages are supported off the assembly jig.

The payload weight and c.g. are well within the allowable orbiter envelope for the critical mission phases. In addition, the loads imposed by the payload on the cargo bay support fittings are well below the orbiter capability in the maximum load conditions.

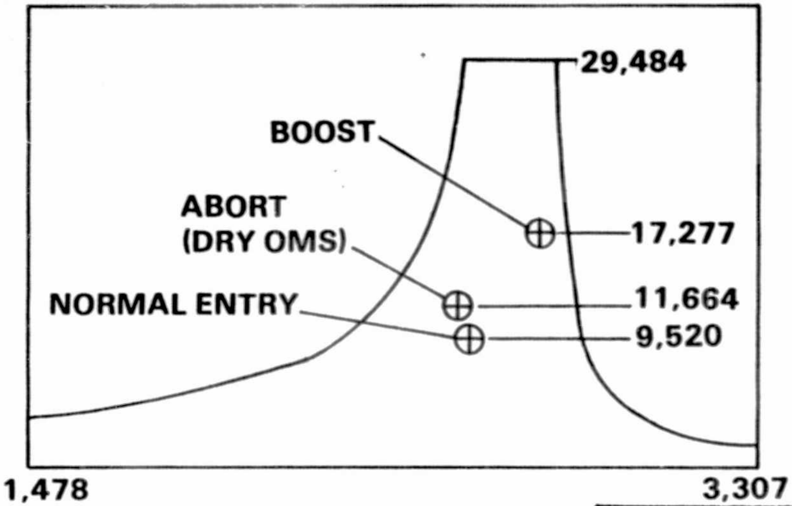
There is both weight and volume available to carry secondary payloads with SCAFE to utilize the orbiter capability to the fullest.

SCAFE STOWAGE CONCEPT

• ARRANGEMENT



• WEIGHT/CG



• SUPPORT REACTIONS

Support Station, X_o (cm)	Reaction Component	Reaction Magnitude (KN)	Orbiter Capability (KN)
1966.0	+Z	+66.3	+278.9
	-Z	-36.5	-302.0
2845.1	+Z	+79.2	+443.9
	-Z	-37.8	-467.0
2964.9	+X	+208.6	+338.0
	-X	-136.6	-338.0
	±Y	±147.2	±459.0
	+Z	+106.3	+519.5
	-Z	-93.9	-462.0

Within allowable limits

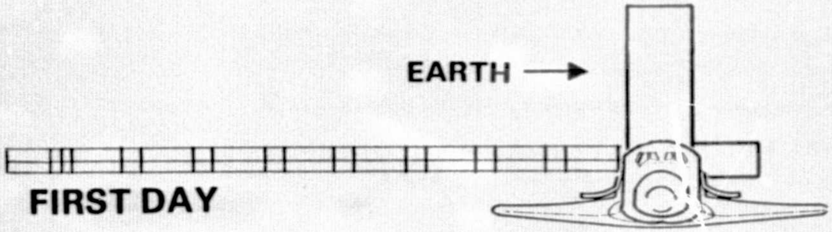
010288082J0263

This and the following chart show the various positions of the beams and platform during successive orbital operations. Upon system deployment from the stowed position, the beam builder, moving to successive positions along the shuttle-attached assembly jig, automatically fabricates four triangular beams, each 200 meters long in the first two days on orbit. Retention of the completed beams is provided by the assembly jig.

The beam builder then moves to the position shown for the third day and fabricates the first of nine shorter, but otherwise identical, cross-beams. After cross-beam attachment, the partially completed assembly is automatically transported across the face of the assembly jig to the next cross-beam location, where another cross-beam is fabricated and installed. This process repeats until the "ladder" platform assembly is complete. The completed platform is then translated back across the assembly jig so that the experiment instrumentation and subsystems can be installed by EVA. The equipment is installed at the assembly jig as the platform is again translated from left to right as shown on the chart. The reason the equipment is not installed as the beam is translated from right to left is that the subsystem package and the solar panels want to be on the end away from the earth and the configuration with the heavy subsystems on the beam 200 meters from the orbiter is undesirable stability-wise.

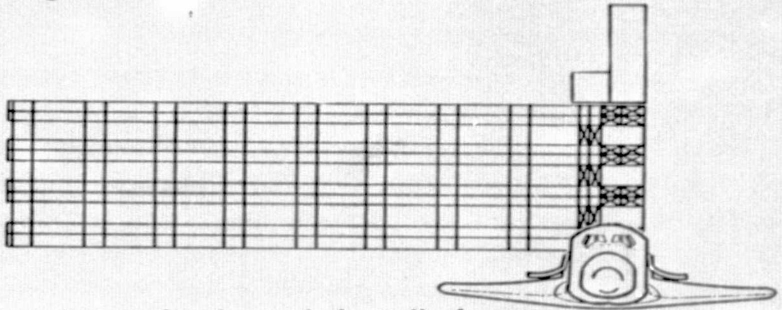
On the fourth day the dynamics response and thermal deflection tests are performed in the configuration shown on the chart.

OPERATIONAL SEQUENCE - I

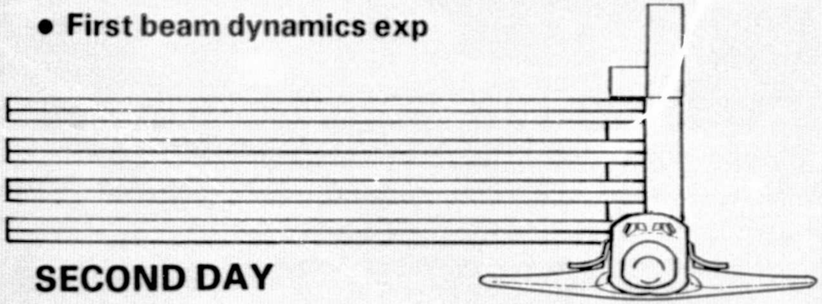


FIRST DAY

- First longitudinal beam fabrication
- First beam dynamics exp

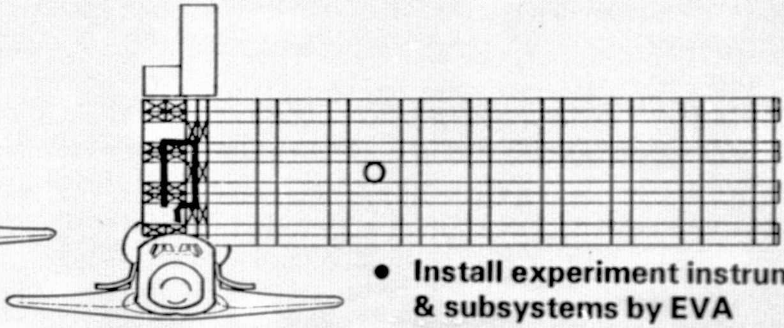


- Translate to begin equip installation

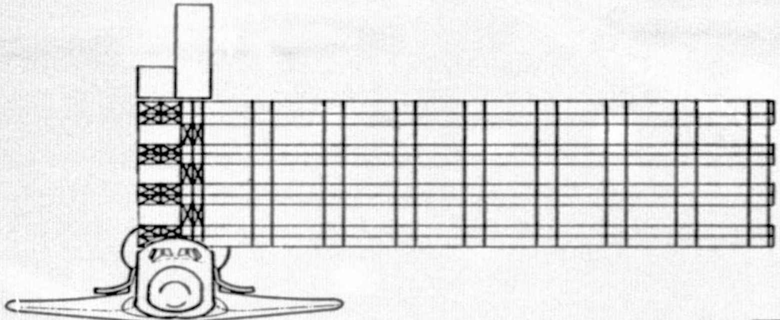


SECOND DAY

- Remaining three beam fabrication

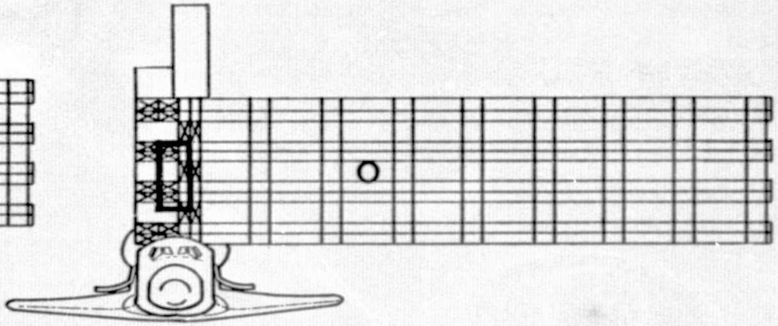


- Install experiment instrumentation & subsystems by EVA



THIRD DAY

- Fabricate & attach nine cross beams



FOURTH DAY

- Platform dynamics response & thermal deflection tests

Note: Platform length scale fore shortened by 7 to 1

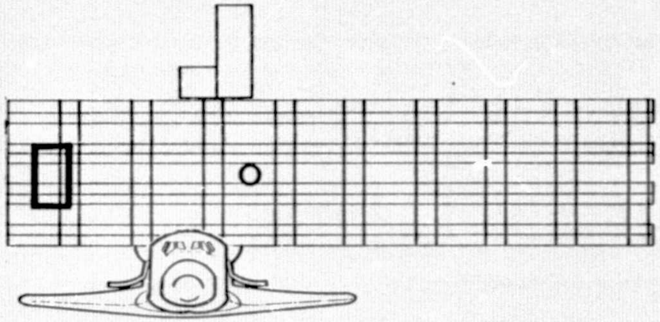
010283082J0268

On the fifth day the separation and recapture demonstration will take place. The beam will be translated to a position where the c.g. is directly above the RMS. The RMS will attach itself to the grapple fitting on the platform and pull the platform away from the assembly jig. The RMS will then detach itself from the platform, leaving it in a free flying mode. The orbiter will position itself a short distance away from the platform in preparation to reacquire the platform. The RMS will be used to attach to the grapple fitting and place the platform back in the assembly jig in a manner so that it can be translated across the assembly jig again to the same position as on the fourth day so that the response tests can be resumed in the afternoon of the fifth day.

On the sixth day the beam will be translated back to the position where the c.g. is over the RMS and an unscheduled maintenance and repair demonstration will be performed during EVA by the astronauts. They will use their Manned Maneuvering Units (MMU's) to traverse along the platform to perform a simulated repair both on the platform itself and on the beam builder.

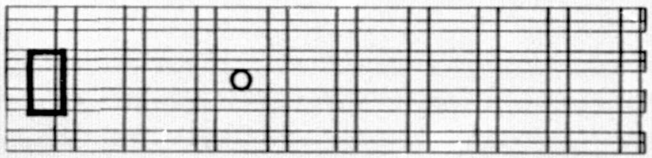
On the seventh day preparation will be made to release the platform for the free flying portion of the mission. The RMS will be used as previously described with the platform c.g. directly over the RMS. After observing the platform for a short time after release, the orbiter will return to earth.

OPERATIONAL SEQUENCE II

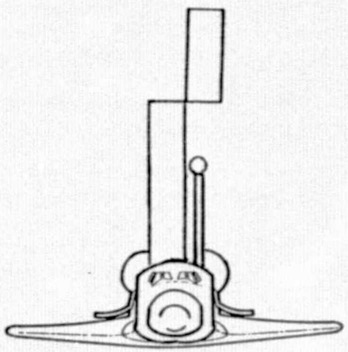


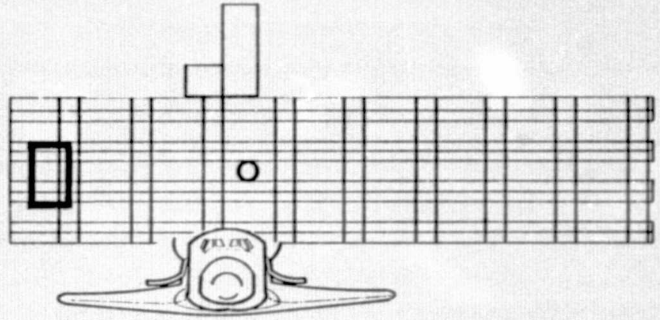
FIFTH DAY

- Separation & recapture demo position
- Resume platform dynamics response & thermal deflection tests



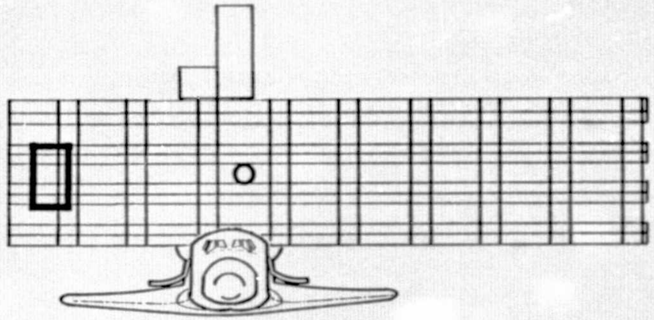
- Platform free-flying





SIXTH DAY

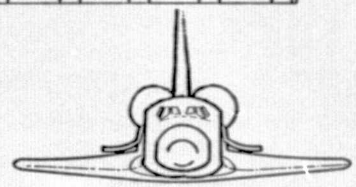
- EVA unscheduled maintenance & repair demonstration



SEVENTH DAY

- Release preparation

- Station keep & observe platform



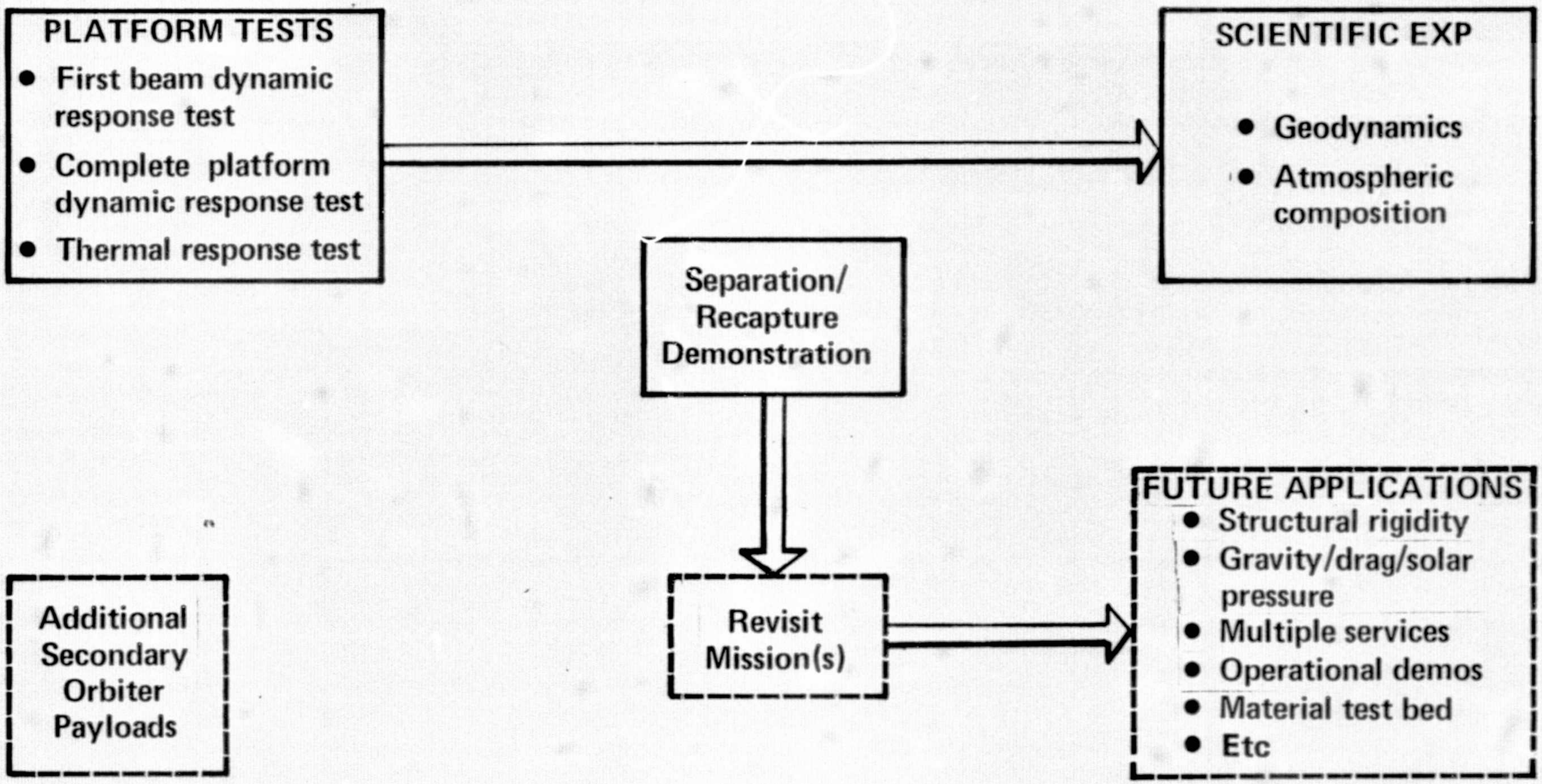
Note: Platform length scale foreshortened by 7 to 1

010288082J0269

During the study Convair concluded several things: one, the objectives of SCAFE can be met with one orbiter mission; and two, the total SCAFE mission needs to be optimized to obtain the most cost effective use of the orbiter and platform resources. The chart shows the elements/functions which should be considered to optimize the total SCAFE mission. Time did not permit this to be accomplished in this study but this should be undertaken in a follow-on study.

However, the elements surrounded by the solid lines were analyzed in this study and approaches to the platform tests and the separation/recapture demonstration were developed and will be explained in detail in the following charts. The scientific experiments used in the analysis were defined previously by JSC and that information was used in this study as representative only of possible applications experiments to be used with the platform. As shown on the chart, there are many other candidates to be considered before the optimum ones are selected.

POST FABRICATION ACTIVITIES



Need to optimize cost effective use of orbiter & completed platform resources

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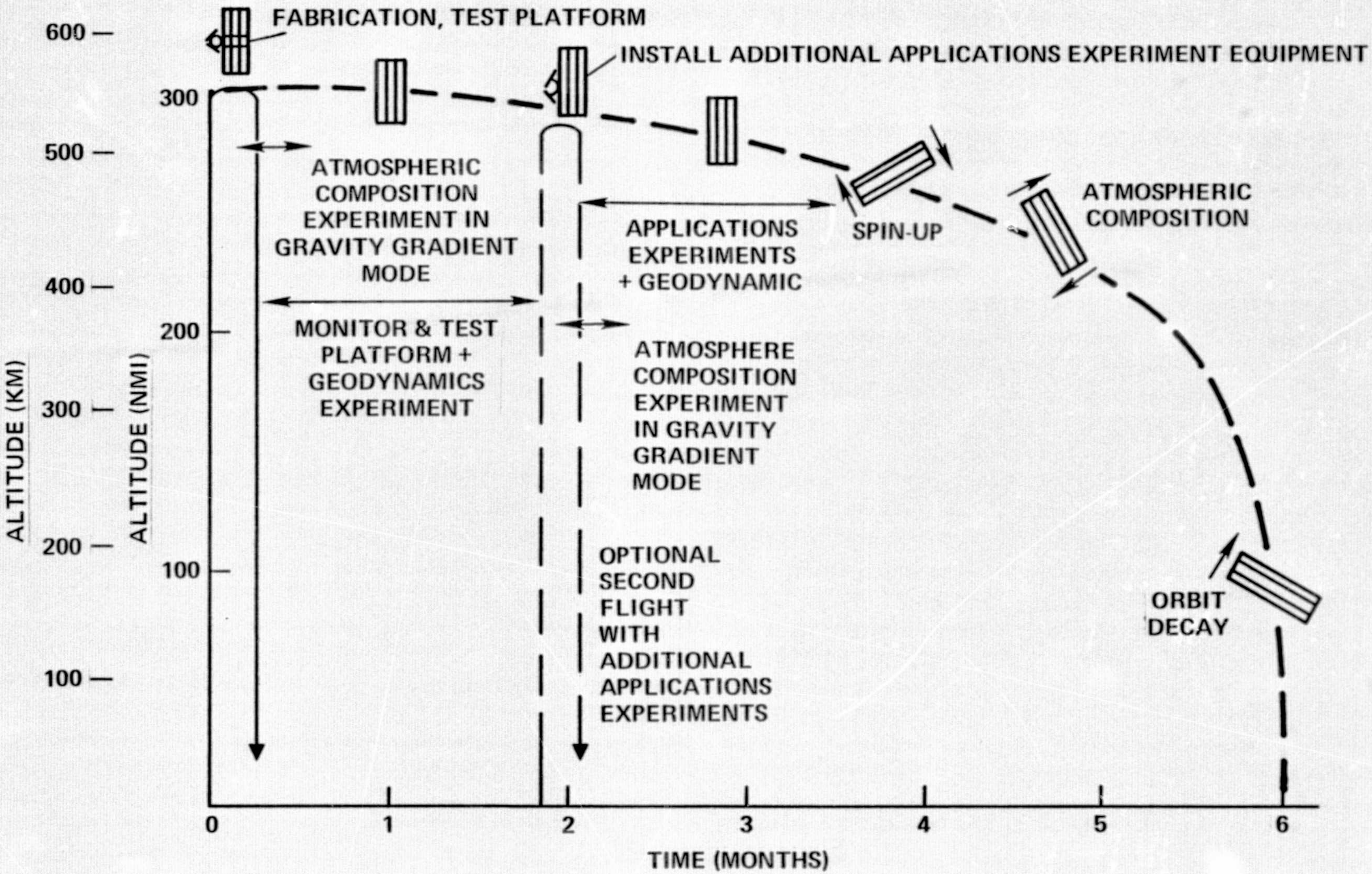
The accompanying chart indicates the SCAFE program mission profile. All the objectives of the SCAFE can be met during the first orbiter flight and within the next 45 days of free-flight. In addition, the equipment for the geodynamics and atmospheric composition experiments can be installed on the platform on the first flight. The atmospheric composition experiment will be performed for a short time after the shuttle departs and the monitoring and testing of the platform and the geodynamics experiment will be performed alternately during the first 45 days of free flight. At that time an optional revisit mission by the orbiter can bring up additional applications experiment equipment. This would be a cost effective use of the platform. If this happened, these experiments could be run for about 45 days before the platform needed to be spun-up to perform the second part of the atmospheric composition experiment. This should be plenty of time to accomplish additional meaningful experiments, taking advantage of the platform already in orbit. If there is not a second flight, the second part of the atmospheric composition experiment can be begun as soon as the platform and geodynamics experiments are concluded.

On a revisit mission, a propulsion stage could be brought up and attached to the platform so that it could be boosted into an elliptical orbit after installation of experiments. This would extend the orbital life of the platform and allow more time to conduct applications experiments.

SCAFE PROGRAM MISSION PROFILE



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This chart identifies the specific objectives of the structural tests to be performed to correlate the actual behavior of the platform in space with the predicted behavior from analysis. In addition it identifies the objectives of the representative scientific experiments attached to the platform.

How the tests and experiments meet these objectives is described in detail on the following charts.

EXPERIMENT OBJECTIVES

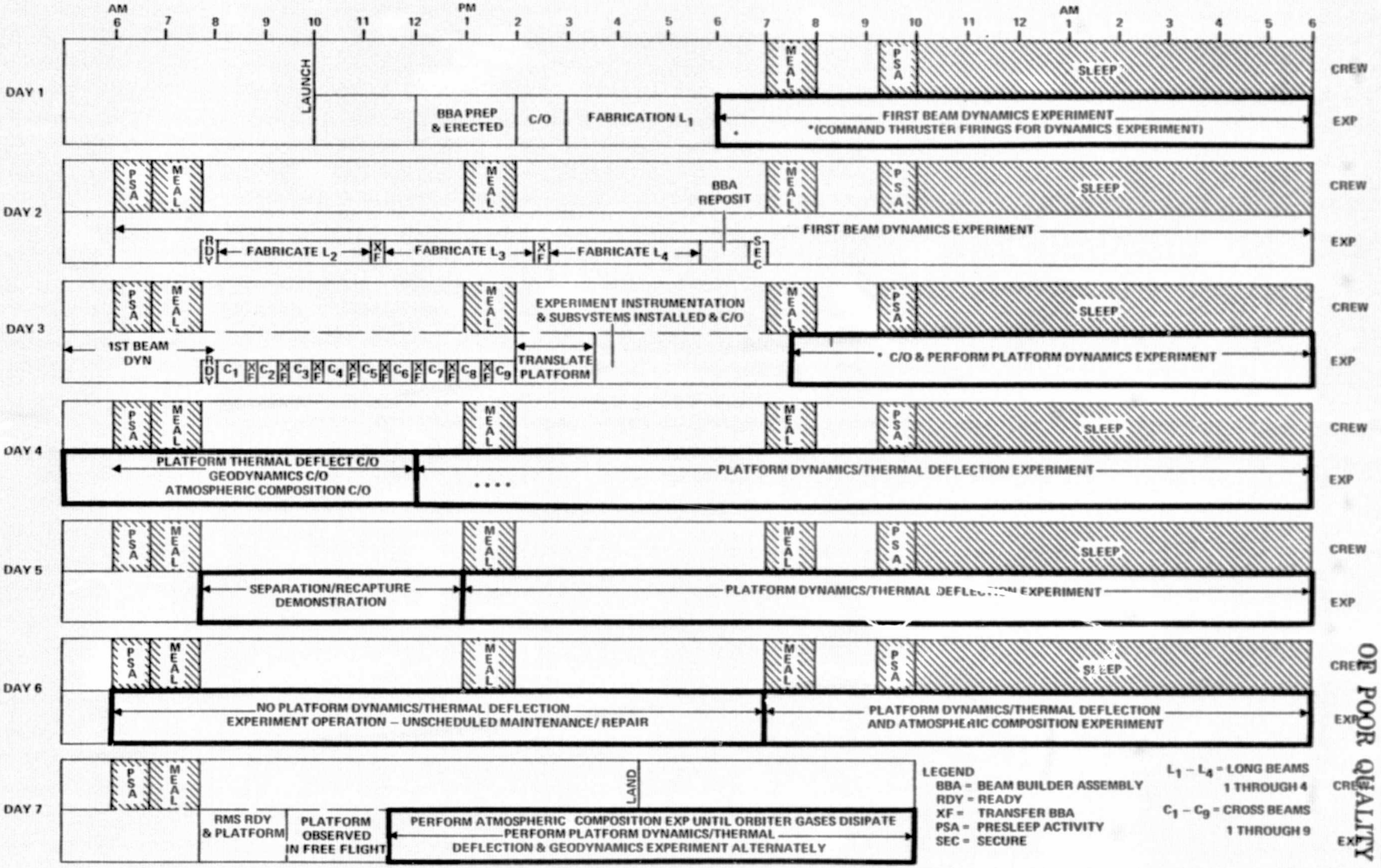
- FIRST BEAM
  - Measure response of first long beam
  - Compare with predictions
  - Revision platform prediction as required
- COMPLETE PLATFORM
  - Measure response of platform
  - Compare with predictions
- THERMAL
  - Measure temperatures
  - Measure induced deformations
- SEPARATION/RECAPTURE DEMONSTRATION
  - Demonstrate RMS attachment
  - Demonstrate positioning with RMS
- GEODYNAMIC EXP
  - Map anomalies in earth gravity field
  - Obtain data on internal mass distribution of earth
- ATMOSPHERIC COMPOSITION EXP

  Measure composition & density of atmosphere at platform altitudes

This chart defines the timeline for the structural response and separation/recapture experiments while the platform is attached to the orbiter. It also indicates the period of checkout for the scientific experiments before free flight of the platform and the atmospheric composition experiment time while attached to the orbiter and just after separation. The crew activities including EVA to go along with the experiments are described on a following chart.

The first beam dynamics experiment begins with the completion of the fabrication of the beam and continues through the building of the other beams until it is time to attach the cross beams. On the afternoon of the third day all of the experiment instrumentation is installed so the platform dynamics experiment can begin. On the morning of the fourth day the other structural tests and scientific experiments are checked out and, starting in the afternoon, the platform dynamics and thermal deflection tests are performed. The separation/recapture demonstration is performed on the morning of the fifth day with the continuation of the response tests after its completion. Unscheduled EVA maintenance and repair is performed on the sixth day. The atmospheric composition experiment is activated on the afternoon of the sixth day to monitor orbiter effluents and continued after separation as appropriate. In free flight the deflection and Geodynamics experiments are performed alternately.

EXPERIMENT TIMELINE



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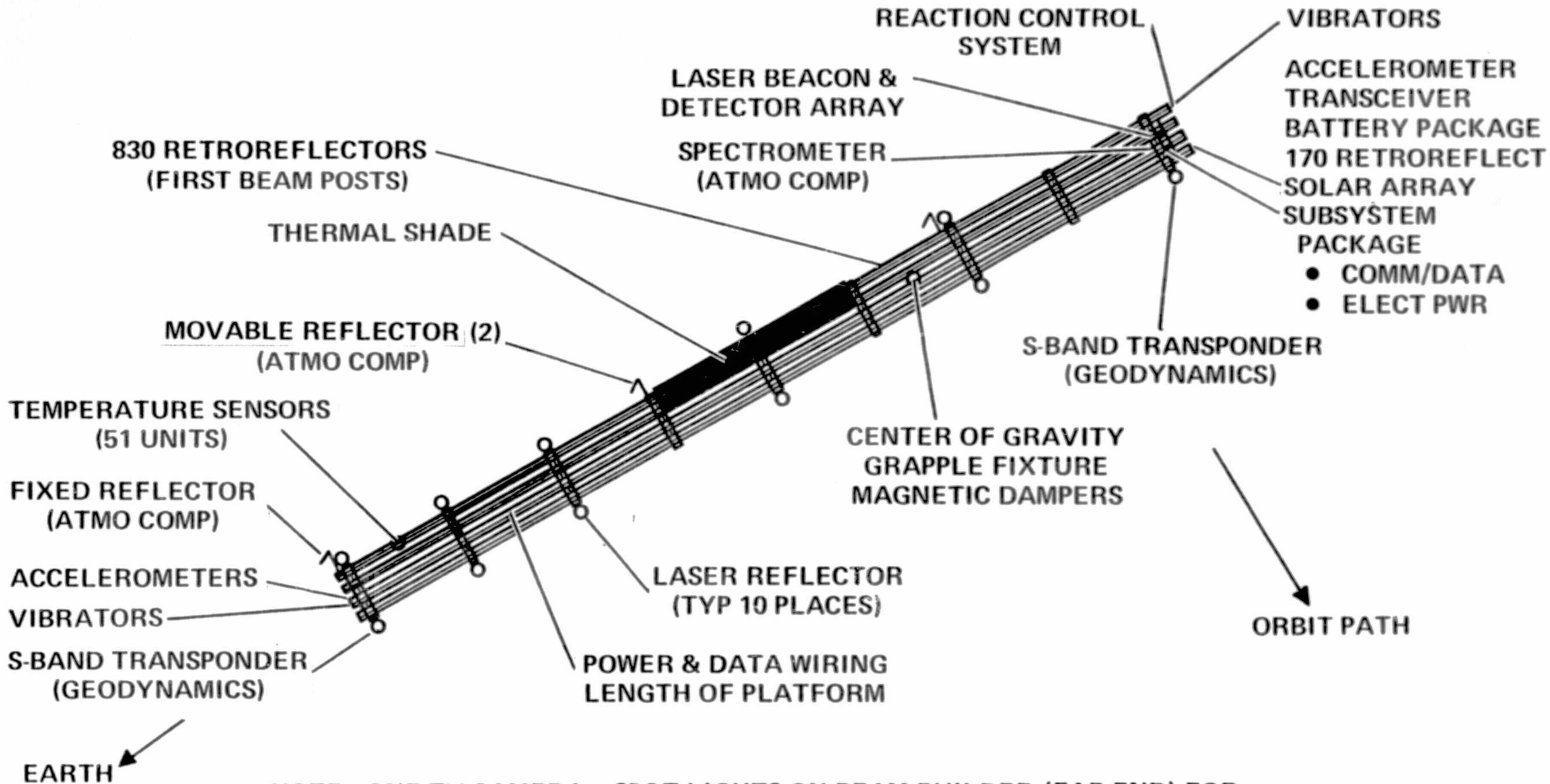
010288082J0296

This chart shows the general arrangement of the equipment on the platform in the free flying configuration. The location of the experiment instrumentation identified in the system diagrams is portrayed here. In addition, the location of the subsystems which support the experiments in the platform free flying mode is also called out. Details of the subsystems are shown on other charts.

The subsystem package is located on the end of the beam pointed away from the earth. The solar arrays are located here to provide power for the experiments. The power and data wiring runs the length of the beam to the various instrumentation along the beam. This equipment is all installed by EVA on the third day after the platform has been constructed.

The grapple fixture will be placed as near the center of mass as possible along with the magnetic dampers which will reduce oscillations due to separation from the orbiter and the environment while the platform is in the gravity gradient stabilized mode with its long axis vertical.

PLATFORM EQUIPMENT GENERAL ARRANGEMENT
(Experiment plus Subsystems)



NOTE: ONE TV CAMERA + SPOT LIGHTS ON BEAM BUILDER (FAB END) FOR FIRST BEAM EXPERIMENT

010288082J0282

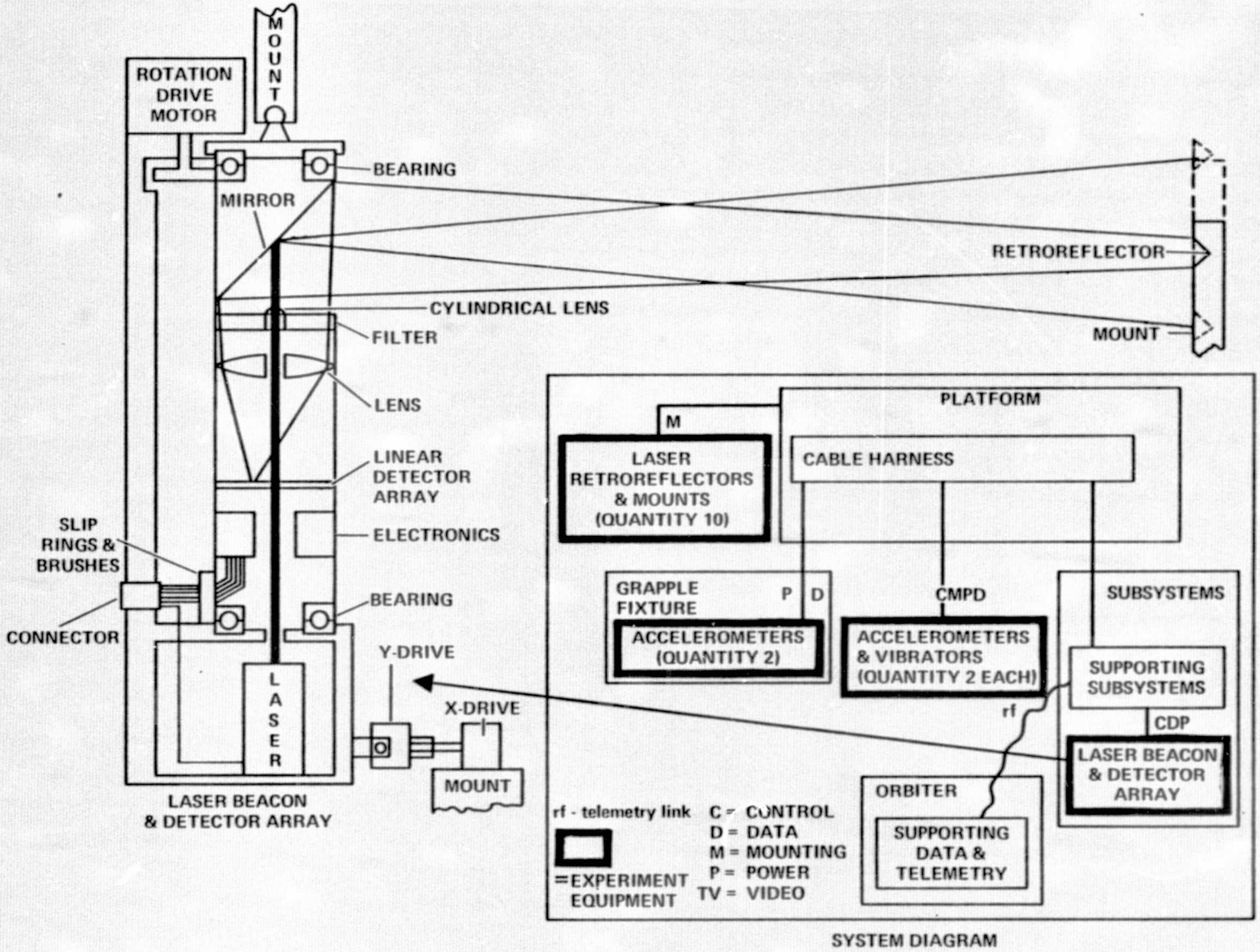
This experiment to meet future applications tolerances on the platform must measure the deflection with a 2.5 mm resolution in the measurements. To track the movements of the platform accurately requires a sampling of 15 Hz. The number of points needed to determine the shape of the platform is 10 for the low frequency modes of interest. The dynamics analysis predicts the maximum expected peak to peak deflection amplitude to be approximately one meter.

The system diagram of the experiment equipment with interfaces to the orbiter, beam builder, platform, grapple fixture, and subsystems rack is shown on the chart. The heart of the experiment is the laser beacon and detector array, which is shown in conceptual form on the chart.

The platform will be excited in its various dynamic modes using the orbiter vernier thrusters and with the vibrators. Data from the instruments will be telemetered to the orbiter and to the ground from the subsystems rack.

The experiment will continue whenever it is convenient to operate the vibrators and laser beacon and detector array. The operation will be on a non-interference basis with other experiments and orbiter operations, including operation in the free-flying mode up to 3 weeks after platform separation.

PLATFORM DYNAMICS INSTRUMENTATION



SYSTEM DIAGRAM

010288082J0283

The experiment requires temperature measurements at 51 locations on the platform to an accuracy of $\pm 5.50^{\circ}K$ over a range from $155^{\circ}K$ to $283^{\circ}K$. The experiment also requires measurement of deflections of the structure to an accuracy of 2.5 mm. In order to produce significant temperature differences in the structure, such as would be expected in future space platforms, it is necessary to deploy a sun shade over part of the platform. The chart shows the locations of the sun shade and temperature sensors. The setup operation requires a crewman to attach a sunshade and temperature sensors to the platform during extravehicular activity.

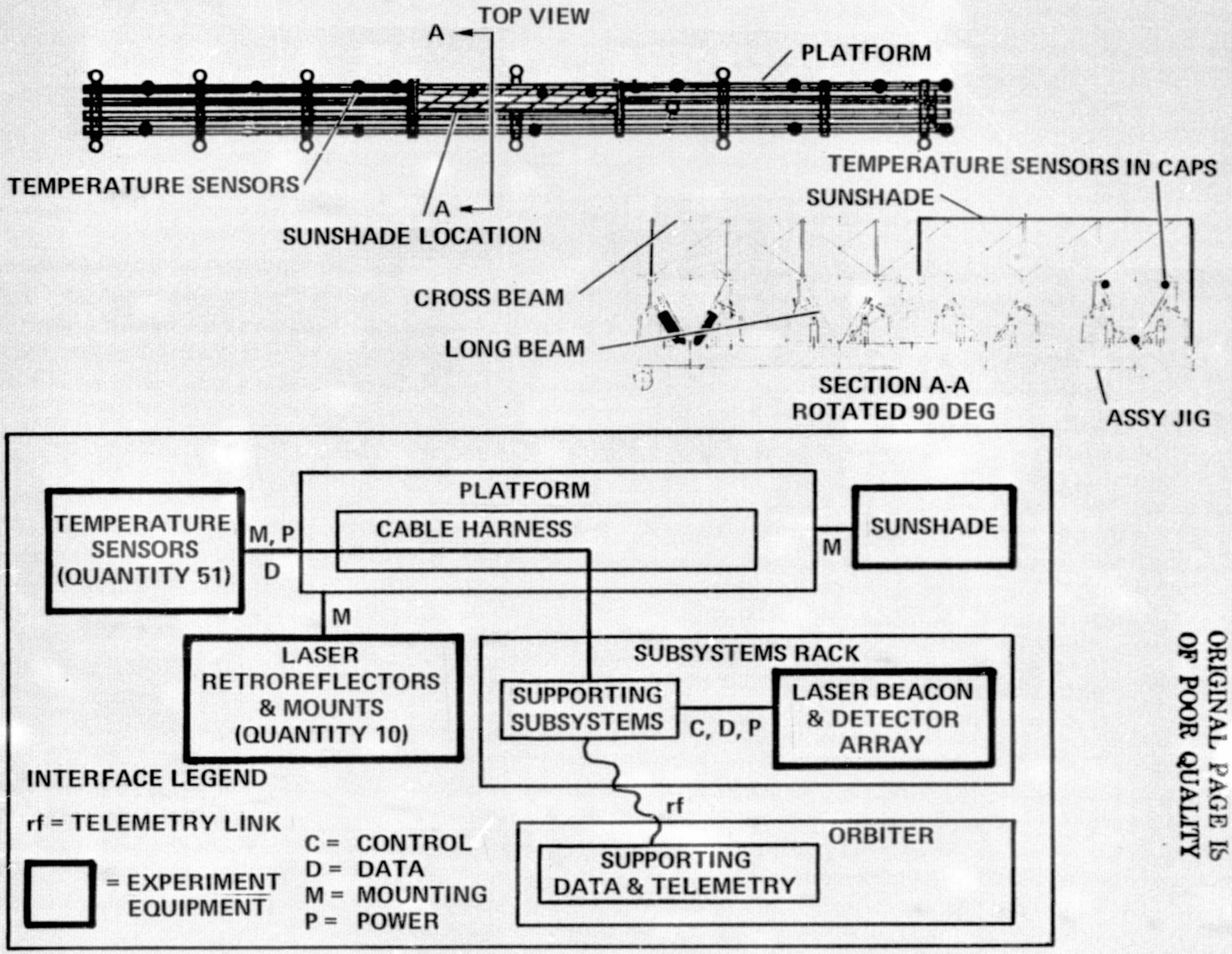
The system diagram shows experiment equipment with interfaces to the platform and subsystems rack. The laser beacon and detector array and laser retroreflectors are used in the complete platform dynamics experiment. The experiment concept is to cause an unsymmetrical temperature distribution in the platform by using a sunshade, and then measure the temperature pattern and distortion of the platform.

There are 51 temperature sensor units, each of which has two temperature probes. The units are mounted in triplets; each of the seventeen locations indicated on the chart will receive 3 units, one in each of the three caps in the beam.

The sunshade is installed after the temperature sensors because it will cover part of the beams where the temperature sensors are located. The crewman will attach the sunshade mounts to one cross-beam, unroll the sunshade to the next cross-beam, attach more mounts, and unroll the sunshade to the next cross-beam, where he will attach the rest of the mounts.

Temperature measurements will be made continually at a low sampling period of approximately 10 seconds to read out the 102 measurements. The deflection experiment will primarily be a daylight operation. As the platform heats unevenly on the day side of the orbit, the laser beacon and detector array will measure the deflection of the platform.

THERMAL RESPONSE EQUIPMENT



010288082J0295

Design and operations analysis showed that the most desirable method, simplest jig design and safest operation, was to use the RMS to engage the platform at a grapple fitting and move it clear of the assembly jig. This demonstration will separate the platform from the assembly jig, separate the platform from the remote manipulator system and move the orbiter away from the platform. The requirement is safe separation, with measurement of the undocking loads to an accuracy of 10%.

The recapture demonstration will show that the platform can be attached to the remote manipulator, placed into the assembly jig, locked down and moved by the assembly jig along the platform axis. The requirements are safe docking, measurement of the docking loads to an accuracy of 10%, and movement of the platform by the assembly jig in a reasonable length of time. For this demonstration, safe docking means that the platform touches only the remote manipulator and the assembly jig, and the loads are within the specified limits.

This demonstration will provide important information for an optional second mission, when additional applications experiments may be attached to the platform, and future missions where larger structures are assembled.

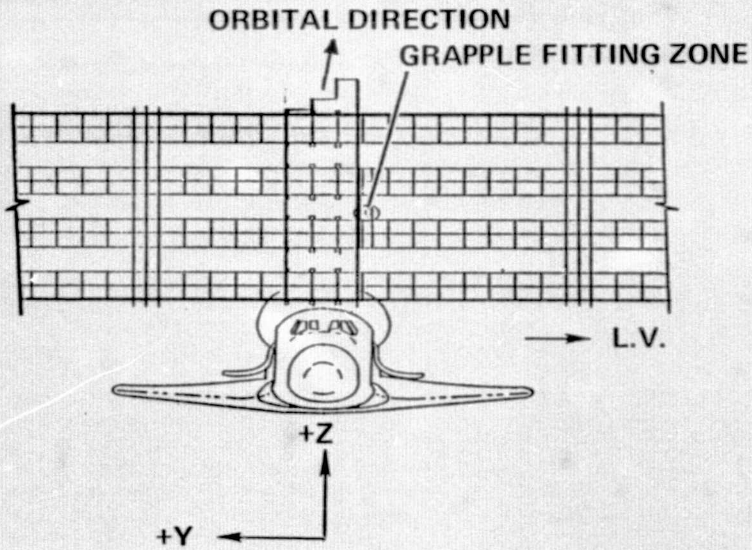
The grapple fitting shown on the chart will be attached to a special support which can be spot-welded to the face of a beam by manual action during installation of equipment on the platform. The support will be attached to the face of the caps in the two center longitudinal beams such that the grapple fitting lies in the center of the platform as close to the center of mass as is practicable. The chart also shows how the RMS captures the grapple fitting (courtesy SPAR).

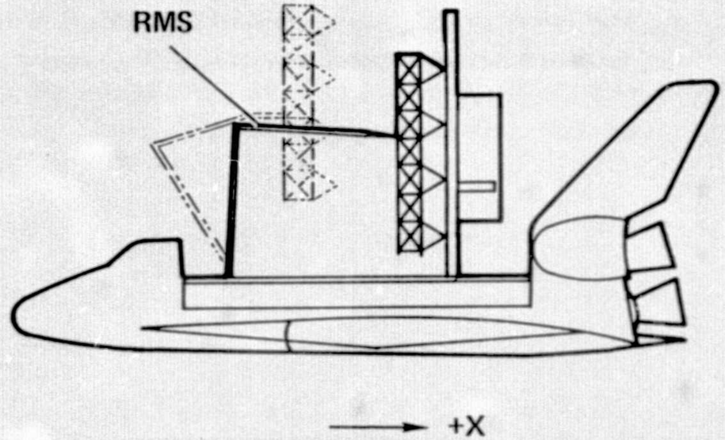
Two accelerometer packages are mounted on the grapple fitting support near the fitting. These instruments measure the loads experienced at the fitting during capture, translation and release of the platform. The chart shows the position of the platform in the jig and the reach envelope of the RMS to attach to the grapple fitting.

A crewman will guide the remote manipulator and effector to the grapple fixture for both separation and recapture. The platform will be released from the assembly jig. Then the platform will be pulled away from the assembly jig with the remote manipulator. When a safe clearance distance is reached (the platform will be released from the remote manipulator) and the orbiter will move away from the platform using vernier thrusters. The platform will be aligned with the long axis along the local gravity vector and with a rotation period equal to the orbital period so that the long axis remains aligned with the local gravity vector. The recapture operation will be a reverse of separation.

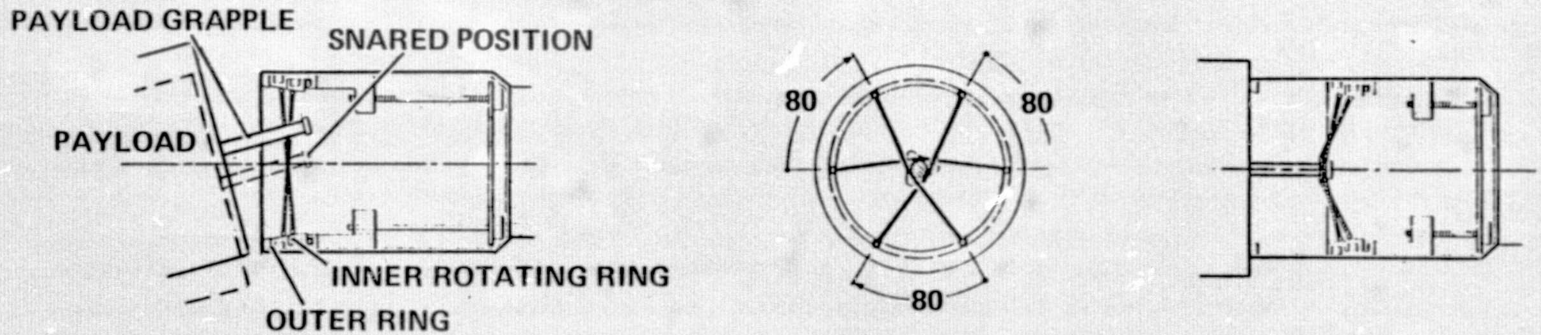
SEPARATION/RECAPTURE DEMONSTRATION

- **RMS COMPATIBILITY**





- **GRAPPLE FITTING/END EFFECTOR**



010288082J0294

Two experiments previously identified and defined by JSC have been chosen as examples of scientific experiments that can be installed on the platform after it has been fabricated on a single orbiter mission and performed using the platform in the free flying mode after the orbiter returns to earth. An in-depth investigation and analysis of candidate scientific experiments to be performed using the platform should be undertaken in future study activities to identify experiments that would be cost effective to be used with the platform and the requirements of these experiments on platform subsystems.

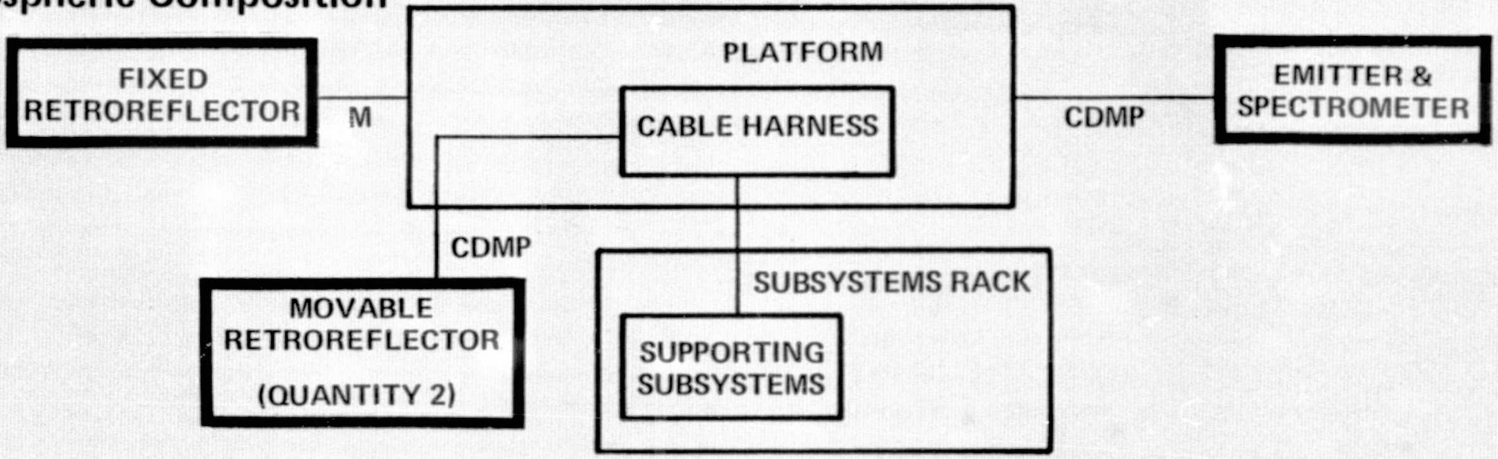
Atmospheric Composition Experiment - The objective of the experiment is to measure the composition and density of the atmosphere at the orbital altitudes of the platform. The approach is to transmit resonance gas radiation sources excited by microwaves through a known path and measure the absorption by spectrometer to determine the composition and density. The radiation source and spectrometer are placed at the end of the platform where the subsystems are located. Reflectors are positioned at various distances along the platform to obtain different path lengths for comparison. Movable reflectors are placed near the radiation source and fixed reflector away from the source and at the end of the platform so that the maximum path length is approximately 400 m.

The experiment is planned to be run just before the orbiter separates from the platform and for a short time after the orbiter separates and leaves in order to measure the dissipation rate of the propellant cloud and contamination in the vicinity of the orbiter. Later on in the orbital mission after all the other applications experiments have been performed, in order to null out the effect of orientation relative to the flight path, the platform will be rotated slowly during experiment data acquisition. In addition, data will continue to be collected to obtain composition and density variation as the orbit decays and the platform enters the atmosphere.

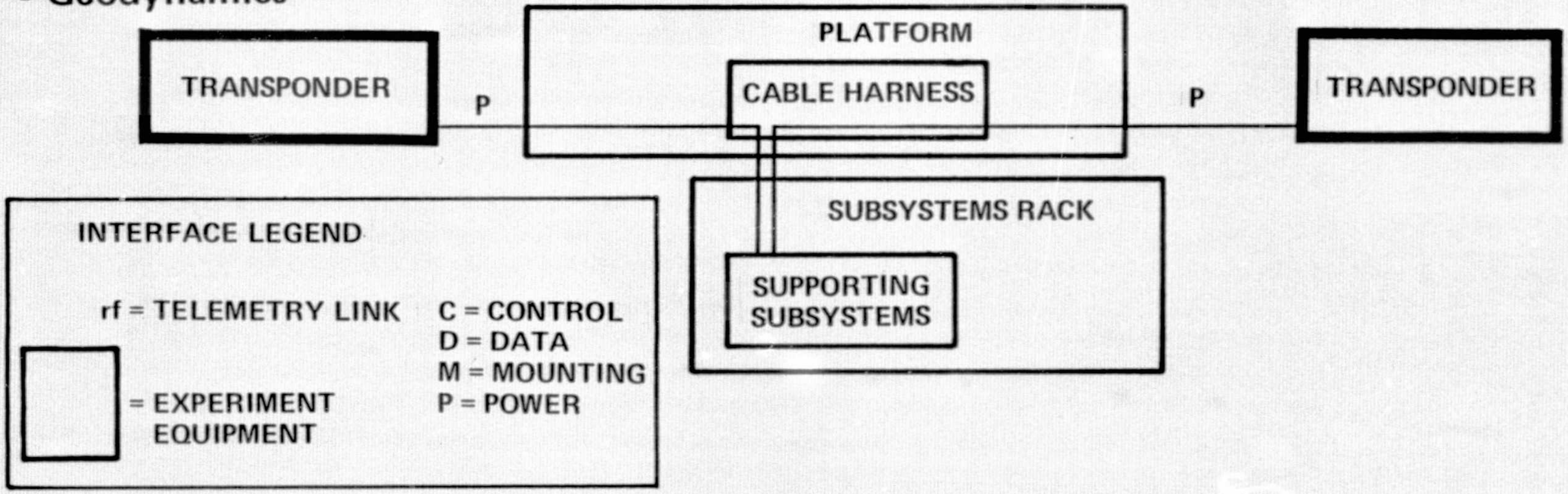
Geodynamic Experiment - The objective of the experiment is to map anomalies in earth gravity field to obtain data on internal mass distribution of the earth. The approach is to use doppler frequency shift of communications from the platform, in a stabilized gravity gradient attitude and with transponders at each end 200 meters apart, to the TDRSS and the platform to the ground tracking stations to detect platform acceleration caused by lateral variations in the gravity field over density anomalies in the earth's structure.

SCIENTIFIC EXPERIMENTS SYSTEM DIAGRAMS

- **Atmospheric Composition**



- **Geodynamics**



010288082J0285

This chart lists some of the major categories of additional experiments and operations which should be considered in an overall system study of the platform and its applications in the follow-on study in order to optimize its effectiveness to develop the capability to perform future operational missions. An example of sub categories is shown for the demonstration missions. The activities should be considered for inclusion in the first mission, a second or possibly third revisit mission, and for the free flying operation when the orbiter is not attached to the platform.

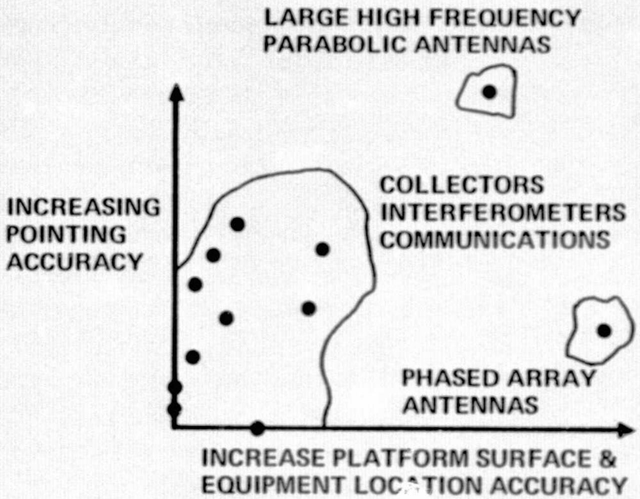
The purpose of a space structure is to position useful elements of some system, subsystem or experiment equipment. From a structural viewpoint, the required positioning accuracy is one useful distinction among the various uses of the structure. This positioning accuracy has two aspects. One is the relative position of different elements on the platform, and the other is the position relative to the orbit, earth, sun, inertial space, a satellite or space probe. The relative position on the platform requires structural dimensional accuracy, while the others require accuracy in attitude control for the entire platform or pointing mounts. Two extreme examples are an exposure facility which mounts samples to be exposed to the space environment, and a deep space tracking antenna for a relay satellite. The exposure facility has no relative position accuracy requirements between elements and practically no attitude requirements on the platform. Exposure type experiments could be performed on the platform with no additional subsystems. However, the exposed samples are to be returned to earth for analysis, so this use of the platform must be done before the final visit of the orbiter to the platform. The chart gives a relative idea of the requirements imposed by various future operational applications.

The scientific experiments described previously are just representative of additional experiments that can be carried up on the first flight and performed along with the structural response tests while attached to the orbiter and during the free flight mode after the orbiter returns to earth. These activities may not represent the most cost effective use of the platform to run precursor operations leading up to the candidate operational missions identified. In addition, no work was done in looking at what additional experiments would be desirable to perform on an optional revisit mission, including raising the platform orbit for longer orbital life. The overall application of the platform as a total system should be studied and optimized by driving out those experiments and operations which will pave the way for future operational missions in the most cost effective manner.

POTENTIAL FUTURE SCAFE PLATFORM ACTIVITIES AND USES

MAJOR ACTIVITIES AREAS

1. Structural rigidity, shape, flatness
2. Structural dynamics
3. Interactions of gravity/drag/solar pressure
4. Operations
5. Multiple services
6. Materials test bed missions
7. Demonstration missions
8. Direct measurement missions



- a Use of trim tabs to supplement attitude control
- b Mounting of solar cells on large structures
- c Night illumination platform demonstration
- d Multiple (public) services mounting platforms
- e Microwave transmission
- f Platform for mounting SEPS demonstration components
- g Radiometer platform
- h Solar collector panel for solar power module/satellite
- i Solar cell annealing procedures for deployed panels

010288082J0279

This chart shows the supporting subsystem installation. The selected subsystems will be composed of standard spacecraft parts to minimize cost.

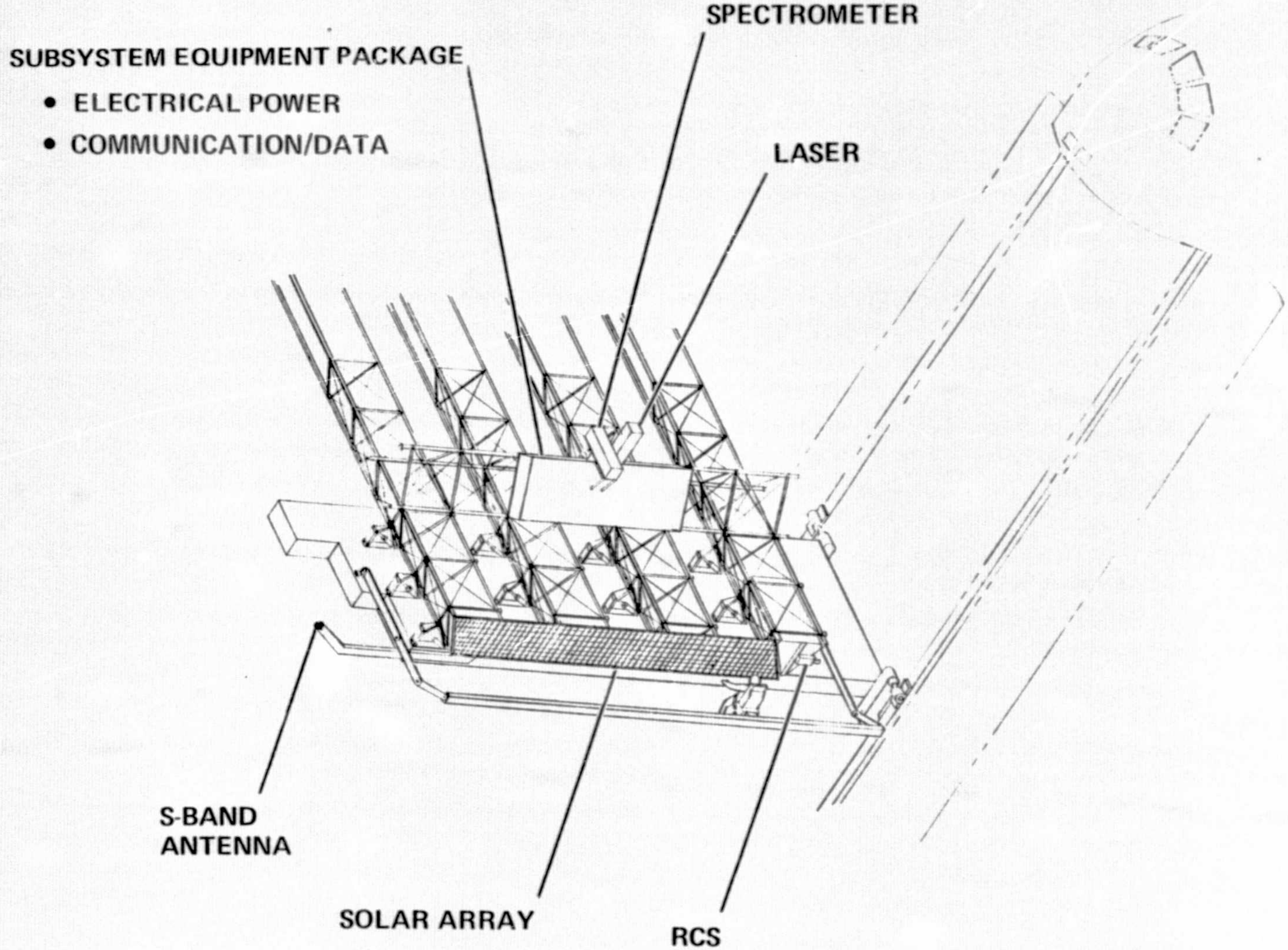
The solar array (approximately 10 square meters) is placed on the end of the platform for maximum exposure to the sun. The batteries and other electrical power system components are contained within the subsystem equipment package.

The platform avionics equipment is also contained within the subsystem equipment package. The platform will require a capability to: a) receive, decode and distribute commands to platform and experiments, b) collect, code and transmit experiment and platform data, and c) provide on-orbit control and monitoring of platform and experiment functions as required. The baseline equipment adopted for these functions is to use multimission spacecraft communication and data handling module. This equipment includes the transponders, data processor and data bus system for distribution of command and acquisition of data. Although this baseline capability exceeds the current capability requirements it is felt that it is a good choice based on a) standard NASA equipment, b) provides for addition of other SCAFE platform and experiment function, c) will be developed, tested and in production during experiment time frame.

The attitude control system is placed in the end of one of the longitudinal beams. It is a cold gas system to be used to spin up the platform near the end of its mission life for the atmospheric composition experiment. Details of the equipment are contained on another chart.

The laser beacon and detector array for the platform dynamics experiment and the spectrometer for the Atmospheric Composition Experiment are shown mounted on top of the subsystem package.

SUBSYSTEM INSTALLATION



010288082J0286

This chart depicts in more detail some of the experiment instrumentation and subsystem equipment installation.

The temperature probe for the thermal effects test is shown installed internally to the beam cap. Fifty-one probes will be used to map the temperature profile of the platform. The probe will be attached to the beam caps by the astronauts using the clamps shown and the data wire hooked up to the main data wire on the wiring shuttle.

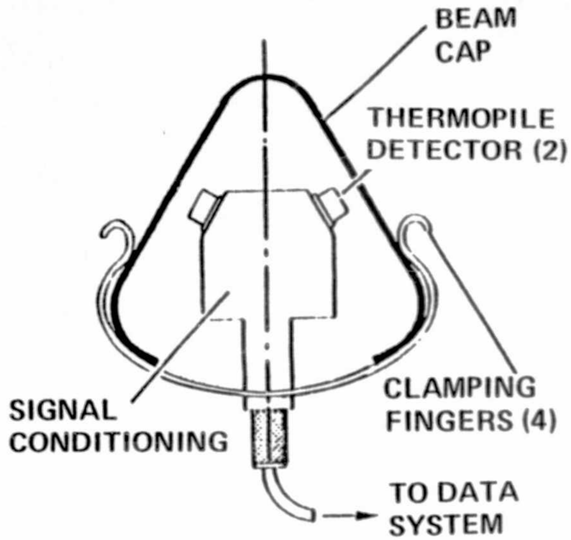
The accelerometer for the platform dynamics experiment will be installed by the astronauts external to the beam cap as shown. The data wire will be hooked up to the main data wire on the wiring shuttle.

The Reaction Control System is packaged in a triangular shaped support structure that the astronauts install at one end of a longitudinal beam. This is a cold gas system for platform spinup and the thruster, tanks, etc. are all integrated into this package.

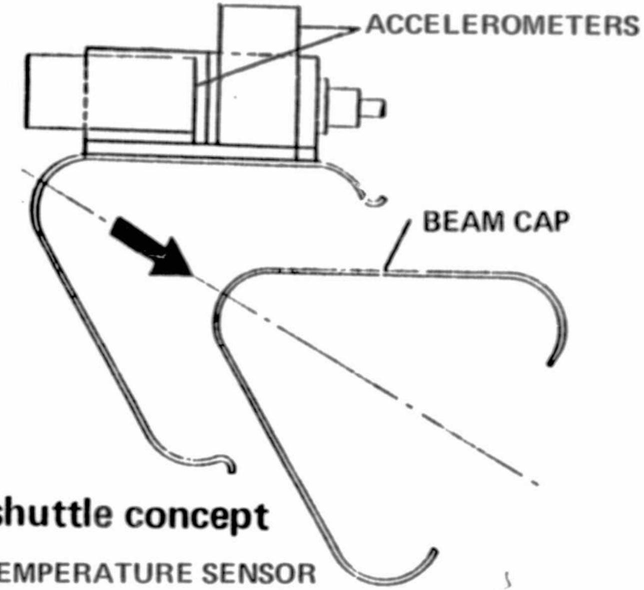
The chart also shows the wiring shuttle concept to be used by the astronauts to string the data and power wire down the beam during equipment installation. The wiring shuttle is translated along the beam and the wires on the reel contain the leads and connectors to be connected to the instruments as they are installed.

INSTRUMENT & SUBSYSTEM INSTALLATION CONCEPTS

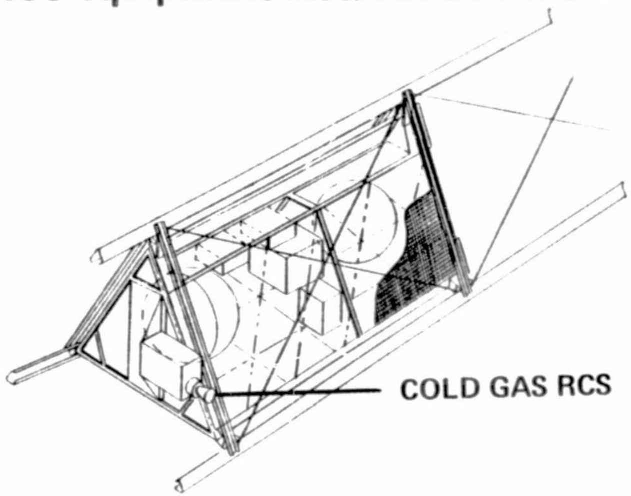
INTERNAL CAP SENSOR



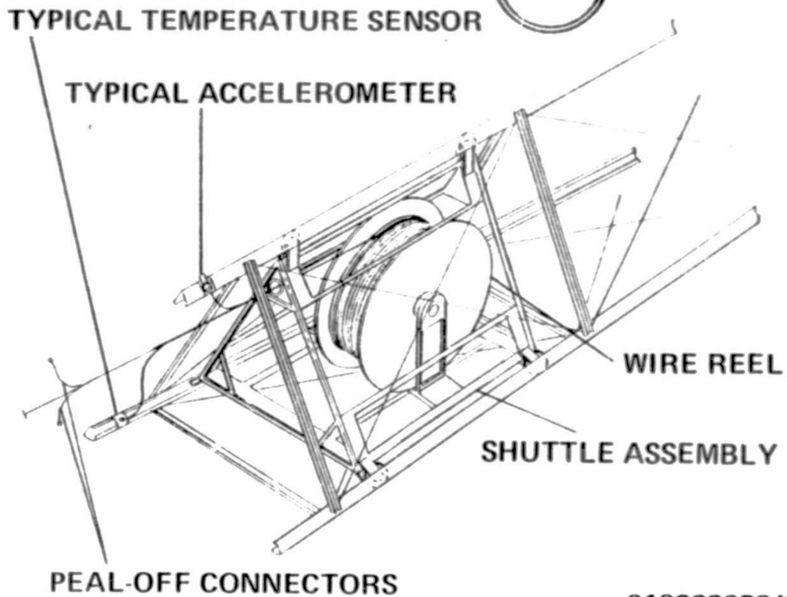
EXTERNAL CAP SENSOR



RCS equipment installation module



Wiring shuttle concept



010288082J0284

This chart depicts the activities scheduled to take place during the seven day flight.

Day 1 EVA, 2.5 hours (5 manhours), will be used to visually inspect the beam builder equipment to assure that it is in the proper configuration prior to starting automatic beam fabrication. Day 1 will also be used to prepare the experiment equipment for installation on the third day. The smaller equipment items will be moved from the orbiter bay and tethered to the EVA carriage. The subsystem unit to be installed on the end of the platform will remain stowed in the orbiter bay until the third day of the mission.

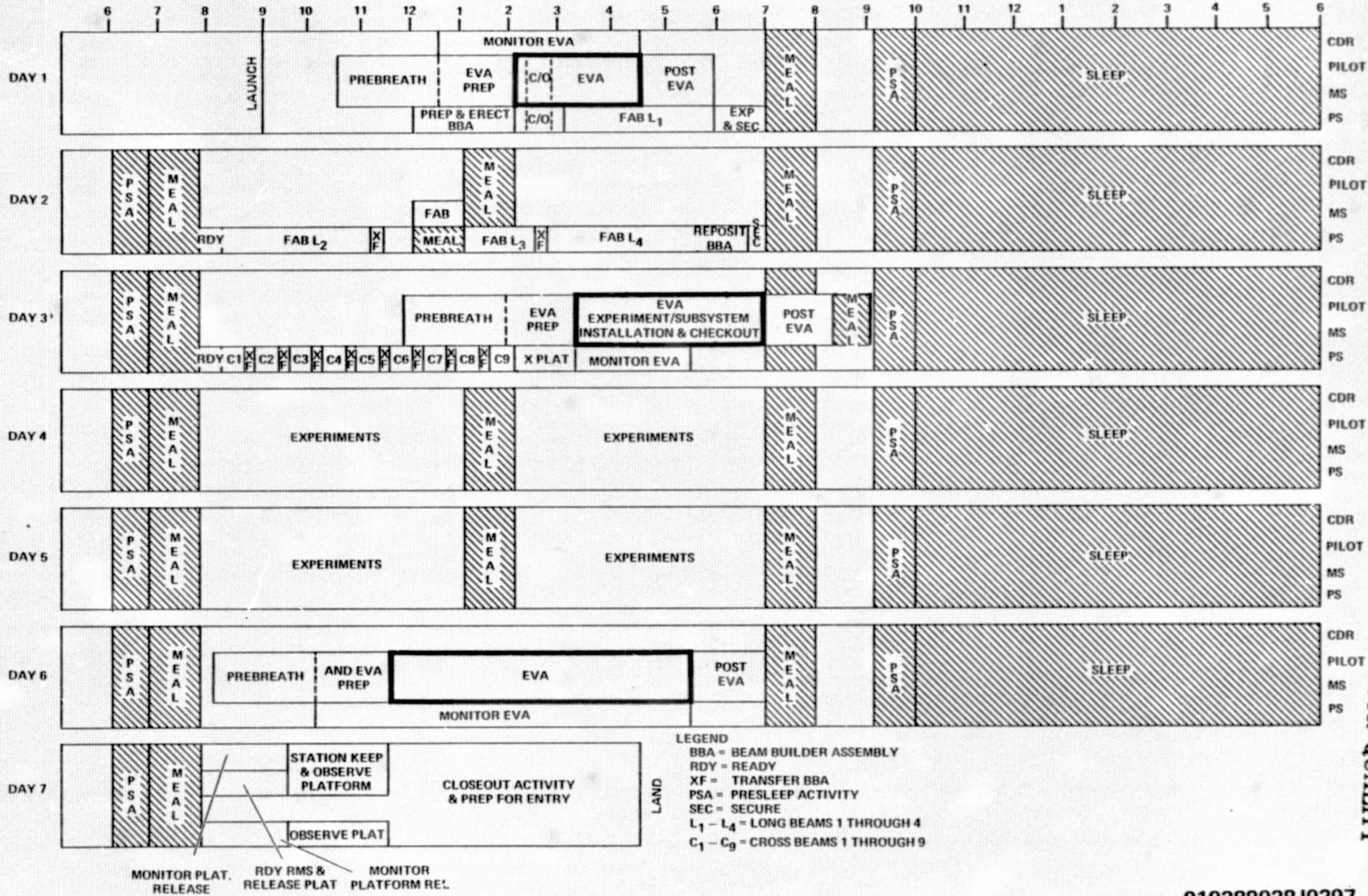
Day 1 EVA will be performed by the mission specialist (MS) wearing his extra-vehicular mobility unit (EMU) and the pilot (PLT) wearing his EMU and a manned maneuvering unit (MMU). The MS will translate to and from work positions using combinations of orbiter provided hand-rails and prepositioned remove manipulator system (RMS). The PLT will translate to and from his work positions with his MMU.

The MS will exit the airlock and translate to erected and locked beam builder and start his visual checks. The PLT will exit the airlock and translate to the MMU station, don and checkout his MMU, and translate to the beam builder assembly to assist the MS. When the checkout of the beam builder assembly, EVA bridge and carriage are complete, the PLT will translate to the experiment stowage area. He will unstow preselected components and transfer them to the MS for tethering in preselected locations on the bridge assembly, for installation on Day 3.

Day 3 EVA, 3.5 hours (7 manhours) will be used to install the experiment equipment. This will be accomplished by translating the platform to preselected positions under the MS, who will be restrained in the EVA carriage work station on the bridge. Hardwiring will be accomplished by the MS and PLT pushing wiring shuttles through the long beams. Day 3 EVA will be performed by the MS and PLT. The EMU and MMU set up will be the same as for Day 1. Day 6 EVA activity is described on a following chart.

GENERAL DYNAMICS
Convair Division

EVA ACTIVITIES



010288028J0297

Day 6 EVA, 6 hours (12 manhours), will be used to demonstrate unscheduled maintenance on the platform. Unscheduled maintenance tasks will include:

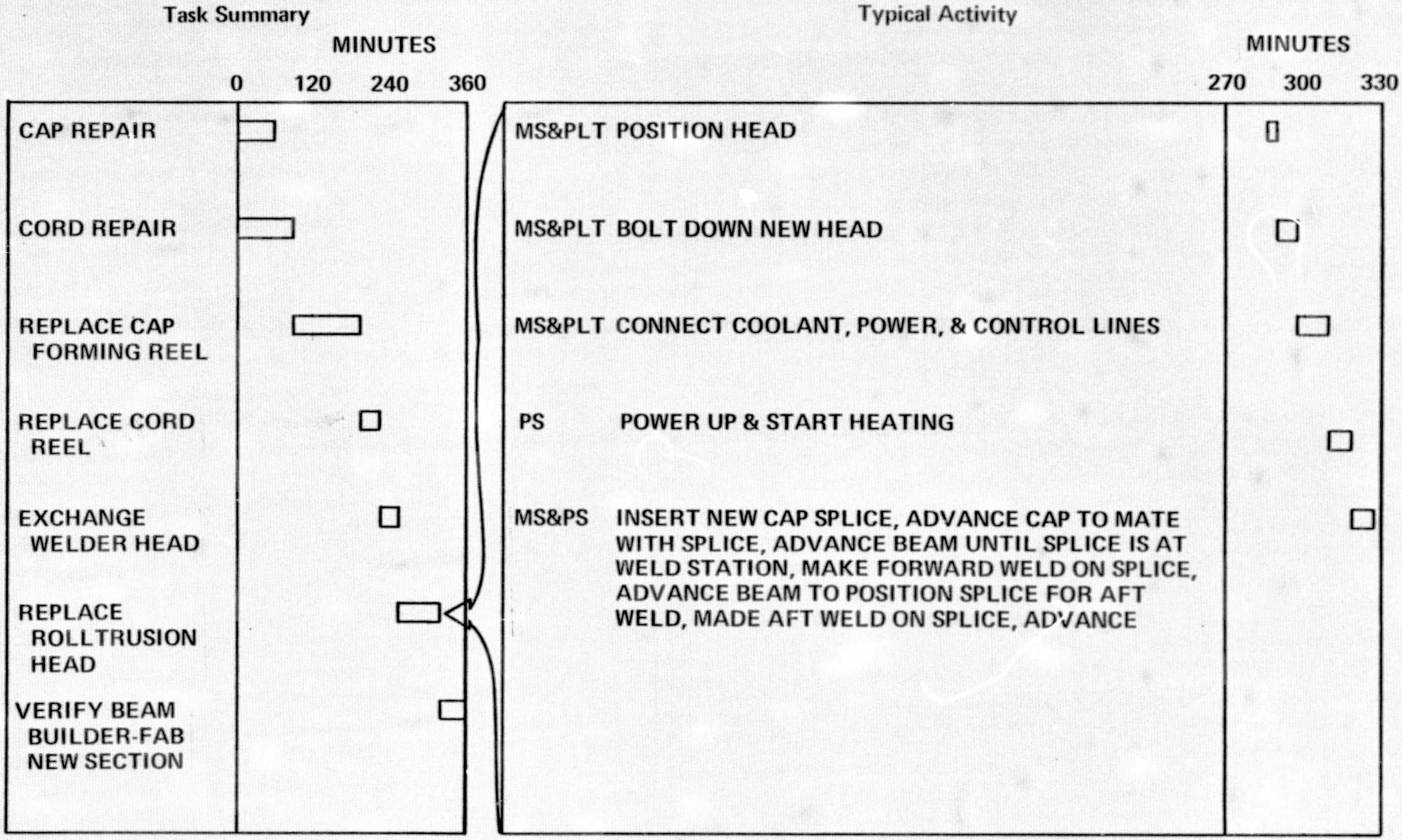
- Platform Repairs
  - Cap Repair
  - Cord Repair

- Beam Builder Repairs
  - Remove and replace cap forming reel
  - Remove and replace cord reel
  - Remove and replace spot welder head
  - Remove and replace roll trusion head

Day 6 EVA will be performed by the MS and PLT wearing EMUs and MMUs. MMUs were selected for their utility as work stations as well as their capability to translate along the beam without physically touching it. The chart shows the overall timeline for the major tasks and a detail timeline for replacing a rolltrusion head.

In the event that all of the experiment equipment cannot be installed in the normal seven day mission a few days extension could be tolerated by the crew provided that extended EVA are not planned for consecutive days. A following chart shows crew equipment and consumables charged to the payload for an extended mission duration.

DAY 6 EVA ACTIVITY
Unscheduled Maintenance



010288082J0277

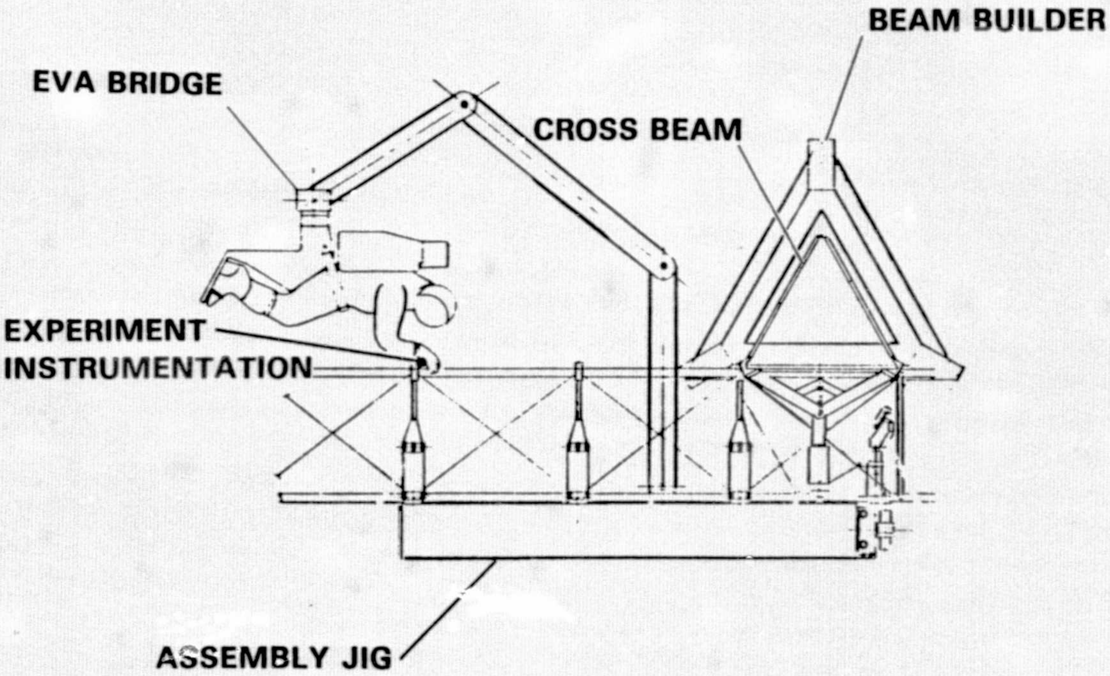
The EVA work station includes all mechanisms and controls required to aid EVA personnel in accomplishing the activities indicated on the chart. The principle aid is the EVA bridge mechanism. This device allows one man to position and support his body over any position on the platform within the reach of the bridge mechanism.

The two control arm assemblies have synchronized motor drives for each link. These control arms move the bridge up and down as well as longitudinally back and forth. A carriage mechanism traverses the bridge to allow lateral positioning of the man restrained by the traveling chair. The chair provides foot restraints as well as body restraints to allow a neutral body position to be maintained.

The chair is equipped with a local control panel to permit the man to manually control his position with respect to the platform. Safety position limit sensors prevent inadvertant collision of the man with the platform. The chair position can also be manually controlled from a second control station located in the payload bay on the end of the assembly jig.

The traveling chair is detached and stowed for flight to allow the EVA bridge to lay flat on the face of the jig.

ASSEMBLY JIG EVA WORK STATION



- EVA CAPABILITIES:
  - VISUAL INSPECTION OF FABRICATION DEPLOYMENT EQUIPMENT
  - SURVEILLANCE OF BEAM CONSTRUCTION
  - REPLACEMENT & REPAIR OF FABRICATING EQUIPMENT
  - EQUIPMENT HANDLING & INSTALLATION
    - EXPERIMENT
    - SUBSYSTEMS
  - DATA & POWER WIRING INSTALLATION & HOOKUP
  - BEAM COMPONENT REPAIR

The Manned Maneuvering Unit (MMU) is an integral part of the EVA activities planned for the astronauts. The chart indicates the provisions the MMU can provide and the activities the astronauts can perform using the MMU. Routine Orbiter inspection has not been timelined into our mission plan at this time.

Day 1 EVA will be performed by the mission specialist (MS) wearing his extravehicular mobility unit (EMU) and the pilot (PLT) wearing his EMU and a manned maneuvering unit (MMU). The MS will translate to and from work positions using combinations of orbiter provided hand-rails and prepositioned remote manipulator system (RMS). The PLT will translate to and from his work positions with his MMU. When the checkout of the beam builder assembly, EVA bridge and carriage are complete, the PLT will translate to the experiment stowage area. He will unstow preselected components and transfer them to the MS for tethering in preselected locations on the bridge assembly, for installation on Day 3.

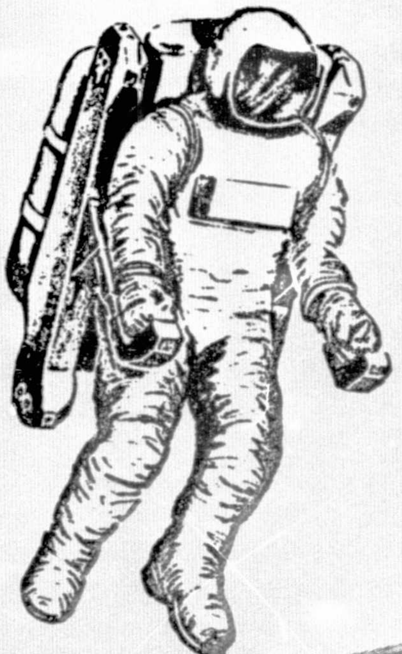
Day 3 EVA will be performed by the MS and PLT, the EMU and MMU set up will be the same as for day 1 and will be used to install the experiment equipment. This will be accomplished by translating the platform to preselected positions under the MS, who will be restrained in the EVA carriage work station on the bridge. Hardwiring will be accomplished by the MS and PLT pushing wiring shuttles through the long beams.

Day 6 EVA will be performed by the MS and PLT wearing EMUs and MMUs. MMUs were selected for their utility as work stations as well as their capability to translate along the beam without physically touching it. The unscheduled maintenance tasks to be demonstrated will include:

Platform Repairs	Beam Builder Repairs
Cap Repair	Remove and replace cap forming reel
Cord Repair	Remove and replace cord reel
	Remove and replace spot welder head
	Remove and replace roll trusion head

MANNED MANEUVERING UNIT (MMU) OPERATIONS

MMU DONNED

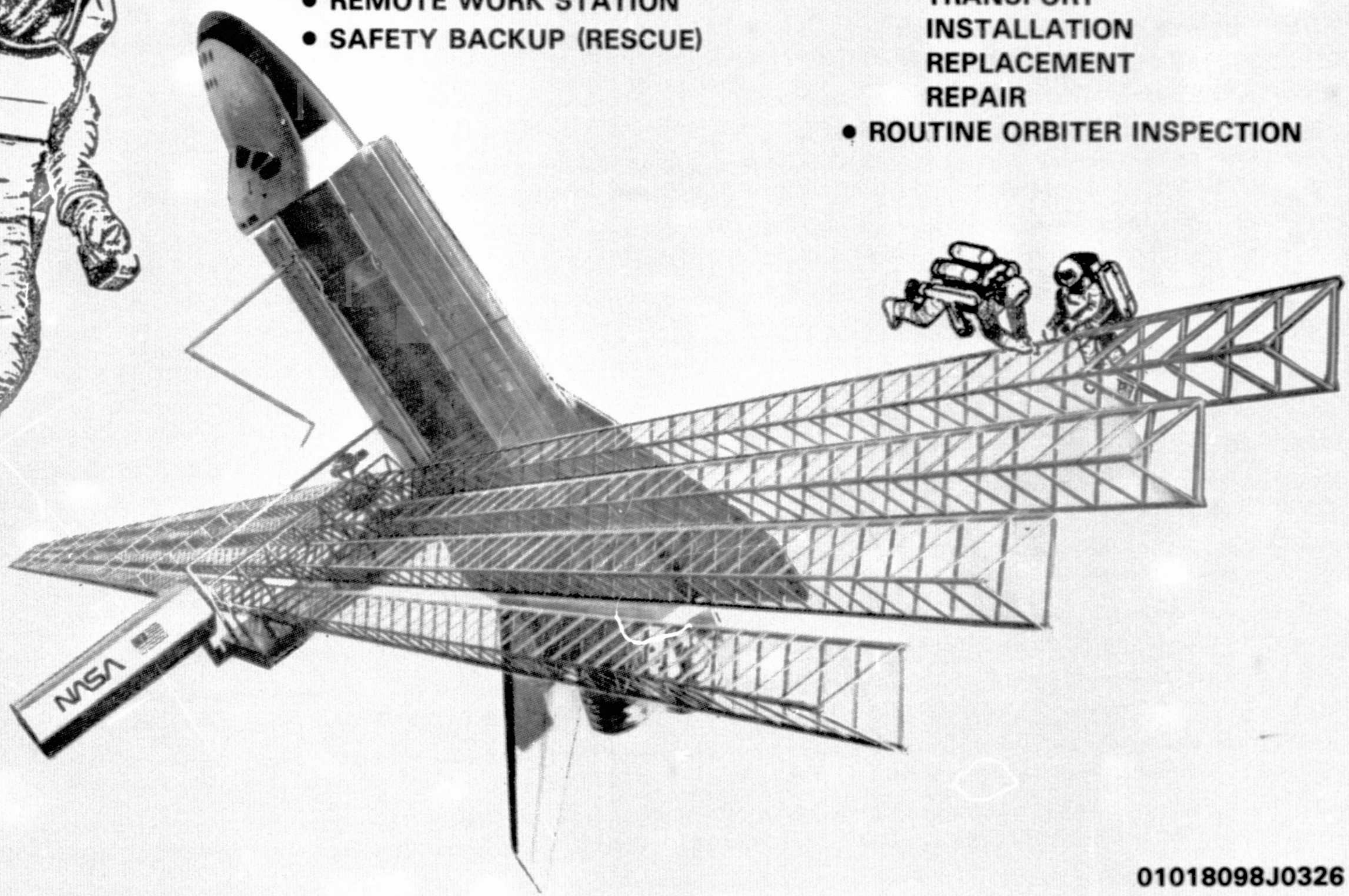


MMU PROVISIONS

- ASTRONAUT TRANSLATION TO SPECIFIED POSITION ON PLATFORM
- REMOTE WORK STATION
- SAFETY BACKUP (RESCUE)

MMU ASTRONAUT ACTIVITIES:

- PAYLOAD EQUIPMENT
  - INSPECTION
  - HANDLING
  - TRANSPORT
  - INSTALLATION
  - REPLACEMENT
  - REPAIR
- ROUTINE ORBITER INSPECTION



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In the event that all of the scientific experiment equipment and supporting subsystems cannot be installed in the normal seven day mission a few days extension could be tolerated by the crew provided that extended EVA are not planned for consecutive days. The chart shows crew equipment and consumables charged to the payload for an extended mission duration. The provision requirements are minimal and it would be most cost effective to extend the mission a day or two rather than require a revisit mission in order to install a total complement of scientific experiments.

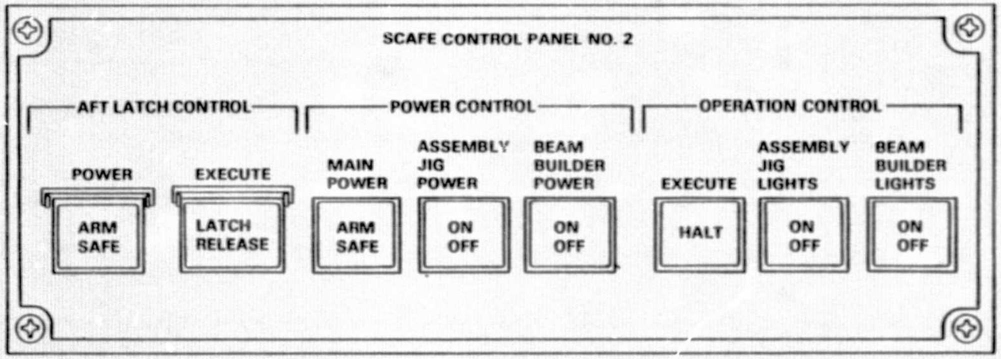
EXTENDED MISSION CREW PROVISIONS

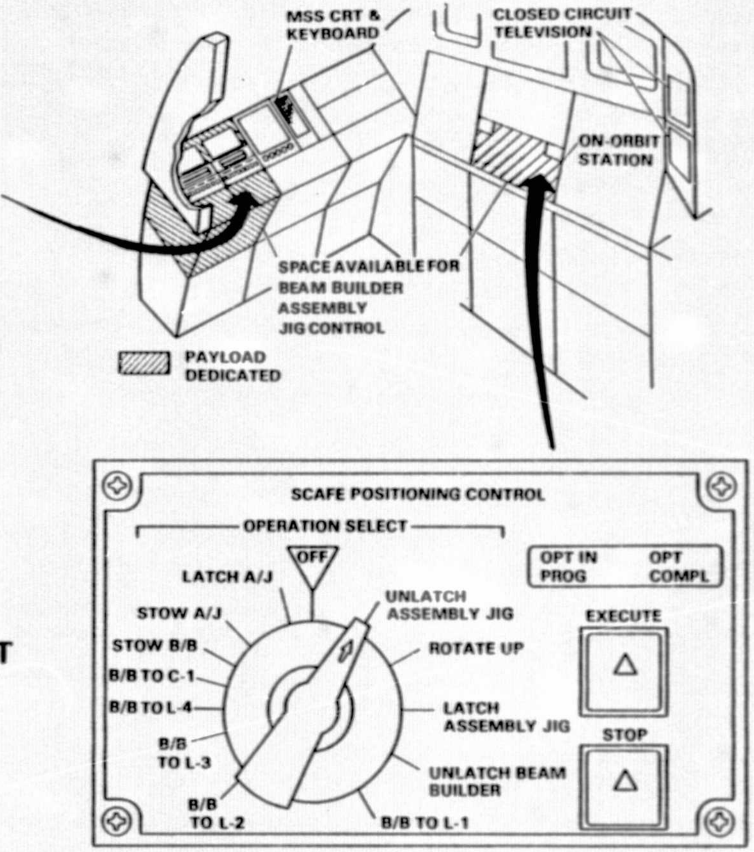
ITEM	WEIGHT (kg)	PAYLOAD CHARGEABILITY
ORBITER		
FOOD	1.51	PER CREWDAY ABOVE BASELINE
LiOH CANISTERS	1.45	OF 28
LiOH CANISTER STOWAGE	0.086	
STOWAGE CONTAINERS	8.78	PER MISSION DAY ABOVE 7
FLIGHT OPERATIONS EQUIPMENT	1.18	
HYGIENE EQUIPMENT	1.27	
CREW PROVISIONS	2.90	
MISCELLANEOUS	0.15	
GN_2 TANK	37.2	ABOVE 7 DAY – TO 14 DAYS
AIRLOCK REPRESSURIZATION		
O_2	1.2	PER REPRESSURIZATION ABOVE
GN_2	3.9	ORBITER BASELINE (24 MH)
EXTRAVEHICULAR MANEUVERING UNIT RECHARGE		
O_2	.72	PER EVA ABOVE ORBITER
H_2O	4.5	BASELINE (24 MH)
BACK PACK LiOH CARTRIDGES	2.5	ONE PER CREWMAN PER EVA OVER TWO
PREBREATH LiOH CARTRIDGES	1.8	ONE PER CREWMAN PER PREBREATH OVER TWO
MMU RECHARGE GN_2	3.0	EACH MMU RECHARGE
TOTAL ONE EXTRA DAY WITH EVA (2 CREWMEN)	72.15	

Extended mission crew provision requirements minimal

Orbiter payload support equipment has been assessed with the result that it is Orbiter compatible. Assembly jig/beam builder executive control will be accomplished primarily via the Orbiter CRT and keyboard located at the Mission Specialist Station (MSS). Control panels for power, lighting and deployment control would be located in payload dedicated areas of the MMS and on-orbit stations (OOS). Additional SCAFE provided TV monitors and their controls are also shown in the payload portion of the MSS. These are provided to extend the Orbiter capability to monitor beam builder and platform fabrication operations. It should also be noted that the payload specialist station volume has been reserved for control and monitor equipment associated with instrumentation located on the beam or assembled platform.

IVA PAYLOAD SUPPORT DISPLAYS & CONTROLS





- **ORBITER COMPATIBLE**
- **ORBITER CRT FOR EXECUTIVE CONTROL & MONITOR**
- **PANELS FOR POWER, LIGHTING/ VIDEO, DEPLOYMENT CONTROL**

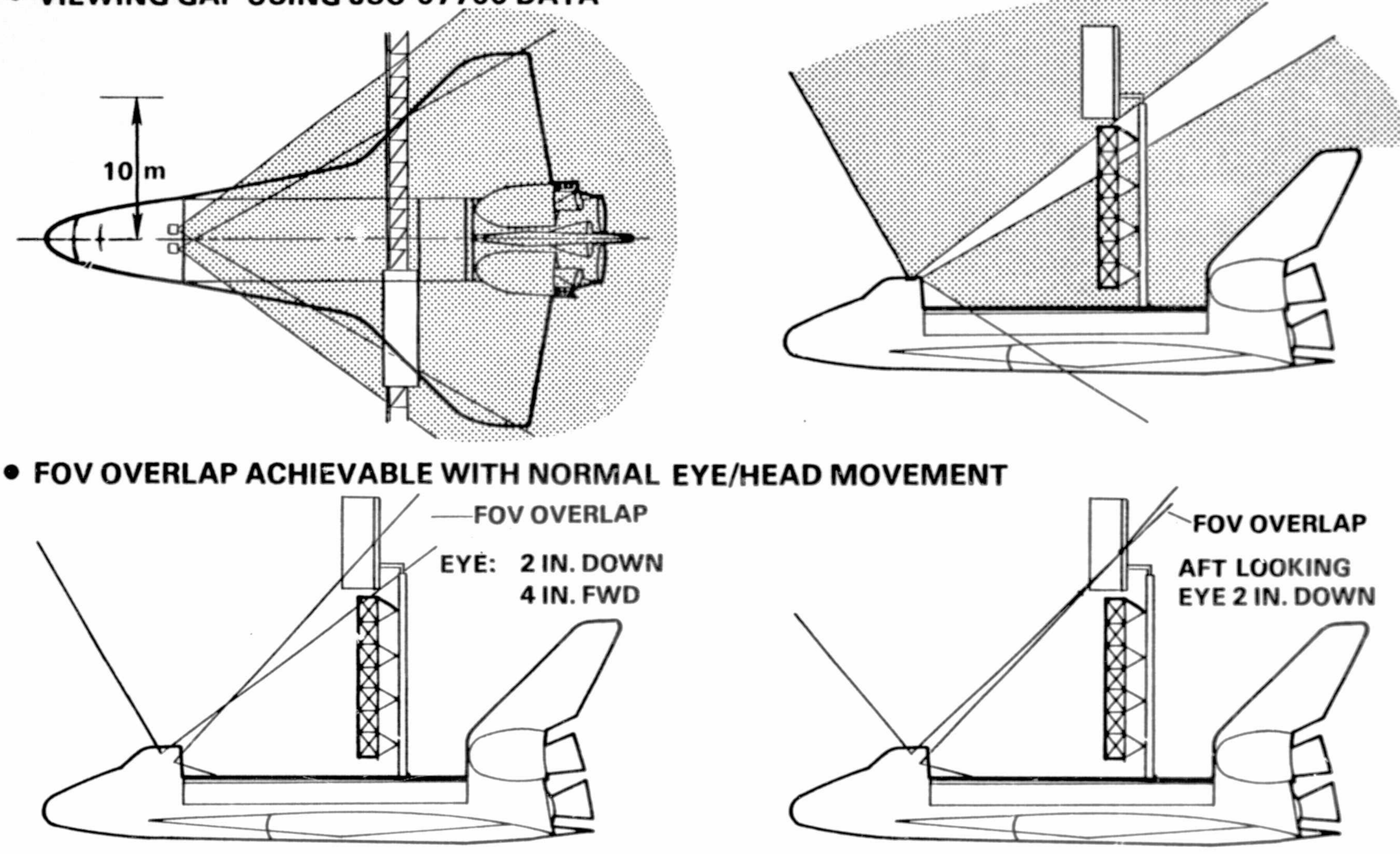
01018098J0324

Initial viewing angle analysis indicate that the visibility looking aft through the cargo bay and overhead windows appears to have blind areas when measured from the given design eye points and utilizing JSC-02700 data for field of vision (FOV).

However, in actuality the observers eye does not remain fixed at any given point and the F.O.V. changes considerably with slight movement of the eye point. The illustrations on the facing page demonstrate the increase in F.O.V. with slight movement of the eye point looking aft (two inches down) and looking through the overhead windows (four inches forward). As is apparent, the blind spots are in effect elimim ted by these slight head/eye movements, which are easily accomplished in the aft orbiter environment.

SCAFE AFT CABIN VIEWING
(Updated)

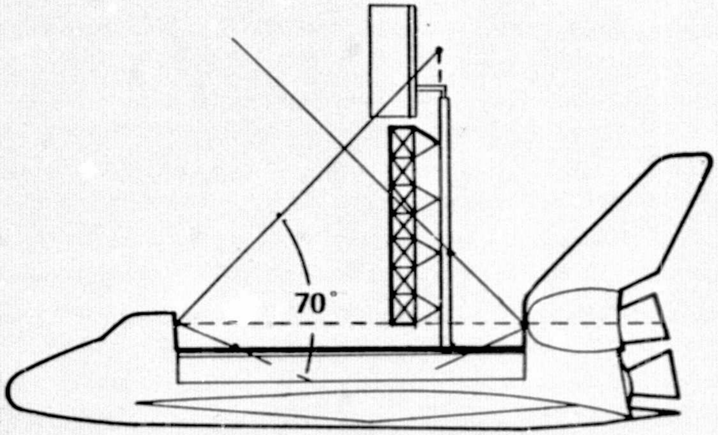
- **VIEWING GAP USING JSC-07700 DATA**
- **FOV OVERLAP ACHIEVABLE WITH NORMAL EYE/HEAD MOVEMENT**

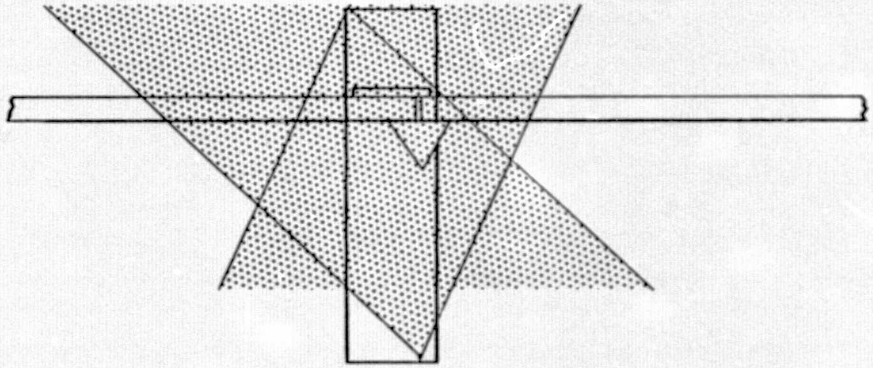


010288082J0306

An analysis was performed of SCAFE operation viewing via the Orbiter standard CCTV cameras located in the cargo bay. The results are indicated in the facing figure. The Orbiter's CCTV cameras fields of view (FOV) cover most of the forward facing surface areas of the SCAFE platform and equipment. The aft side however, falls only within the FOV of the aft bay camera and also cannot be viewed via the RMS camera. This allows viewing of an area of less than 1/3 of the assembly jig and beam builder's (stowed position) height, and less than 6 meters in width.

SCAFE VIEWING VIA ORBITER
CCTV SYSTEMS





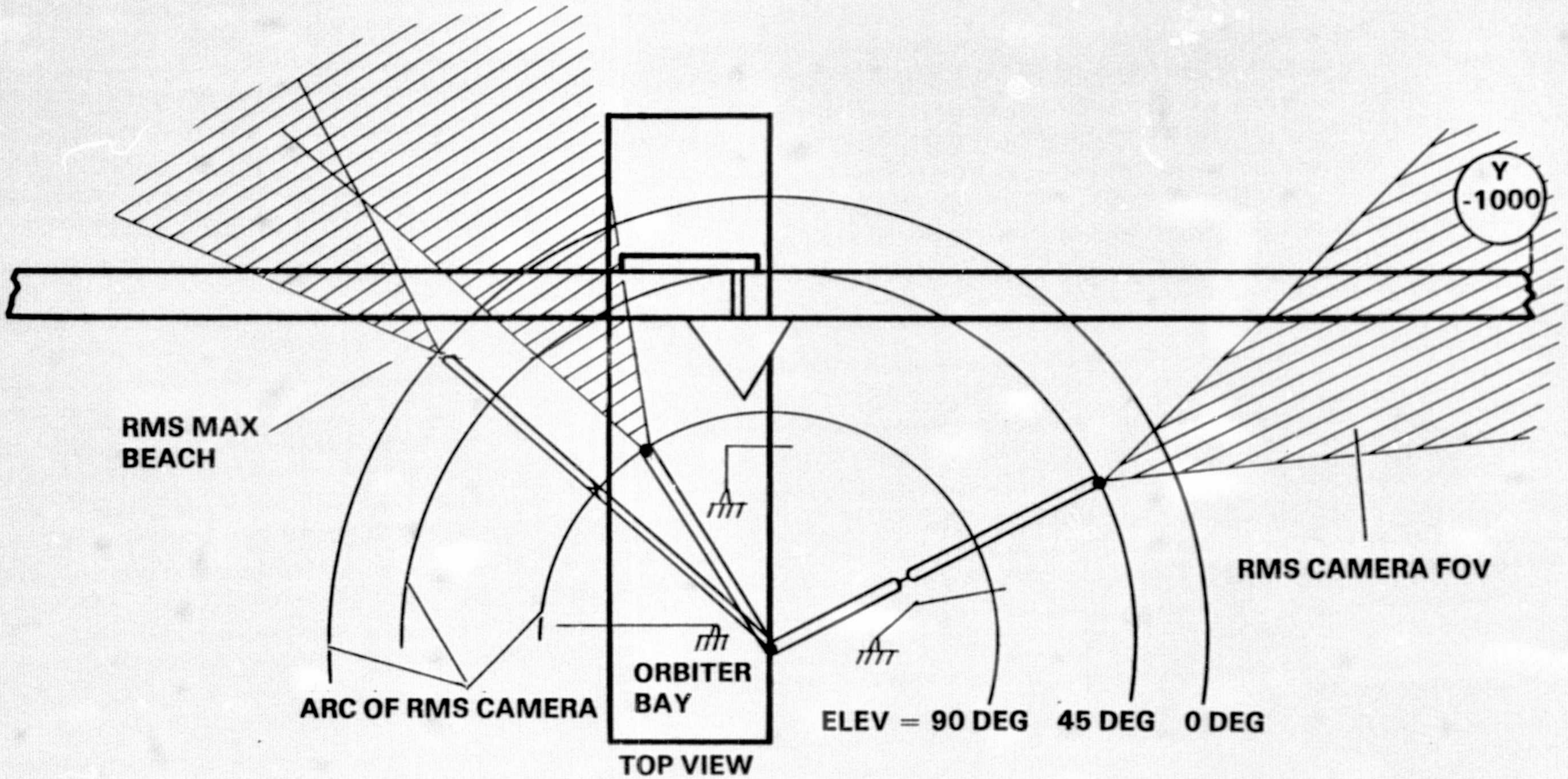
Majority of beam builder & assembly jig forward surfaces within CCTV FOV

Top portion of beam builder out of FOV in cross-beam position

Bottom third of assembly jig in FOV of aft CCTV camera

View and reach capability of CCTV cameras mounted on the RMS were also investigated. The results for three RMS elevation angle configurations are shown in the facing figure. This method allows good viewing of most forward facing beam builder and platform operations. Manipulation of the RMS/camera in close support to a crew member performing EVA tasks, however, needs further investigation to verify crew safety.

ORBITER/RMS CCTV VIEWING ANGLES



Upper arm elevation angle = 0 Deg, 45 deg & 90 deg
Lower arm elevation angle = 0 deg

010288082J0305

PART II FINAL REVIEW

INTRODUCTION

Overview

FLIGHT EXPERIMENT INTEGRATION

Requirements & operations
Tests & experiments
EVA/IVA
Future applications

SYSTEM DESIGN & ANALYSIS

Fabrication systems
On-orbit environment & behavior

PROGRAMMATICS

Development plan & cost

STUDY SUMMARY

Conclusions
Recommendations

01028082J0329

The function of the assembly jig is to automatically assemble the baseline platform. To accomplish this, it must perform the following operations in this sequence:

1. Position and support the beam builder for fabrication of each of four longitudinal beams. This requires a carriage and a roll and turn mechanism, as well as a latching mechanism to secure the beam builder to the jig.

2. Grasp and retain each longitudinal beam in position after it is completed and cut off from the beam builder. This requires a retractable retention and guide mechanism.

3. Position and support the beam builder for fabrication of cross beams. This is accomplished with the carriage and roll and turn mechanism.

4. Advance all four longitudinal beams into position for joining to each cross beam. This is accomplished with a drive mechanism provided for each beam.

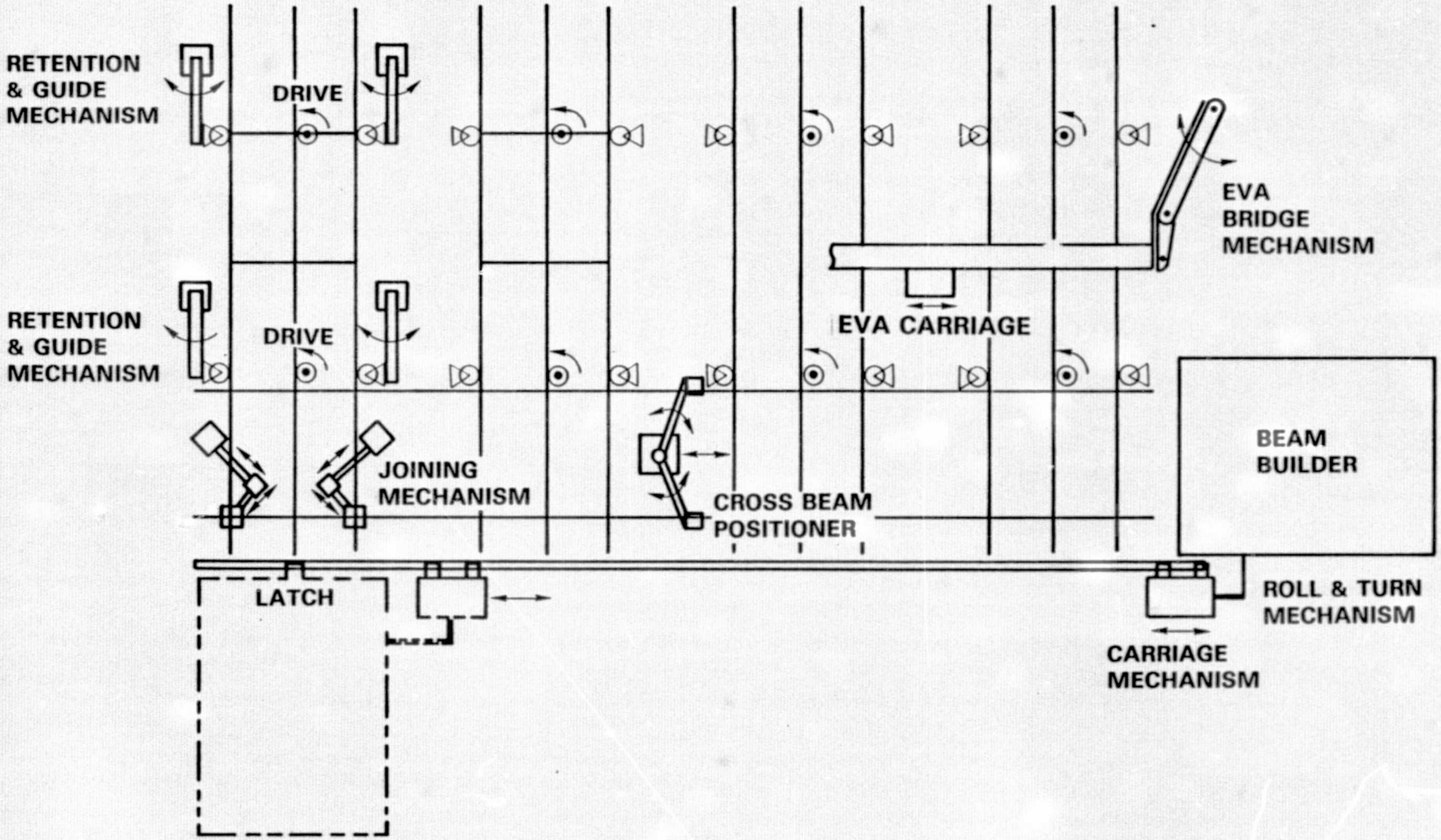
5. Grasp and place each cross beam into position after it is completed and cut off from the beam builder. This requires a cross beam positioner mechanism.

6. Join the cross beam to the four longitudinal beams using automatic joining mechanisms.

7. Permit EVA personnel to traverse the platform and perform equipment installation tasks. An EVA bridge and personnel carriage is required for this purpose.

8. Allow the platform to be quickly released for deployment to space. This is another function of the beam retention and guide mechanisms.

ASSEMBLY JIG FUNCTIONAL DIAGRAM



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The selected assembly jig concept orients the longitudinal beams with the apex towards the jig. This permits all assembly mechanisms to have a fixed position on the jig. Three rows of Retention and Guide Mechanisms (RGM) provide the capability to retract the platform. The cross-beams step through the RGM's as described below:

1. As a cross beam approaches the first row of RGM's, the entire row retracts to clear the cross beam leaving the platform supported by the second and third row of RGM's.

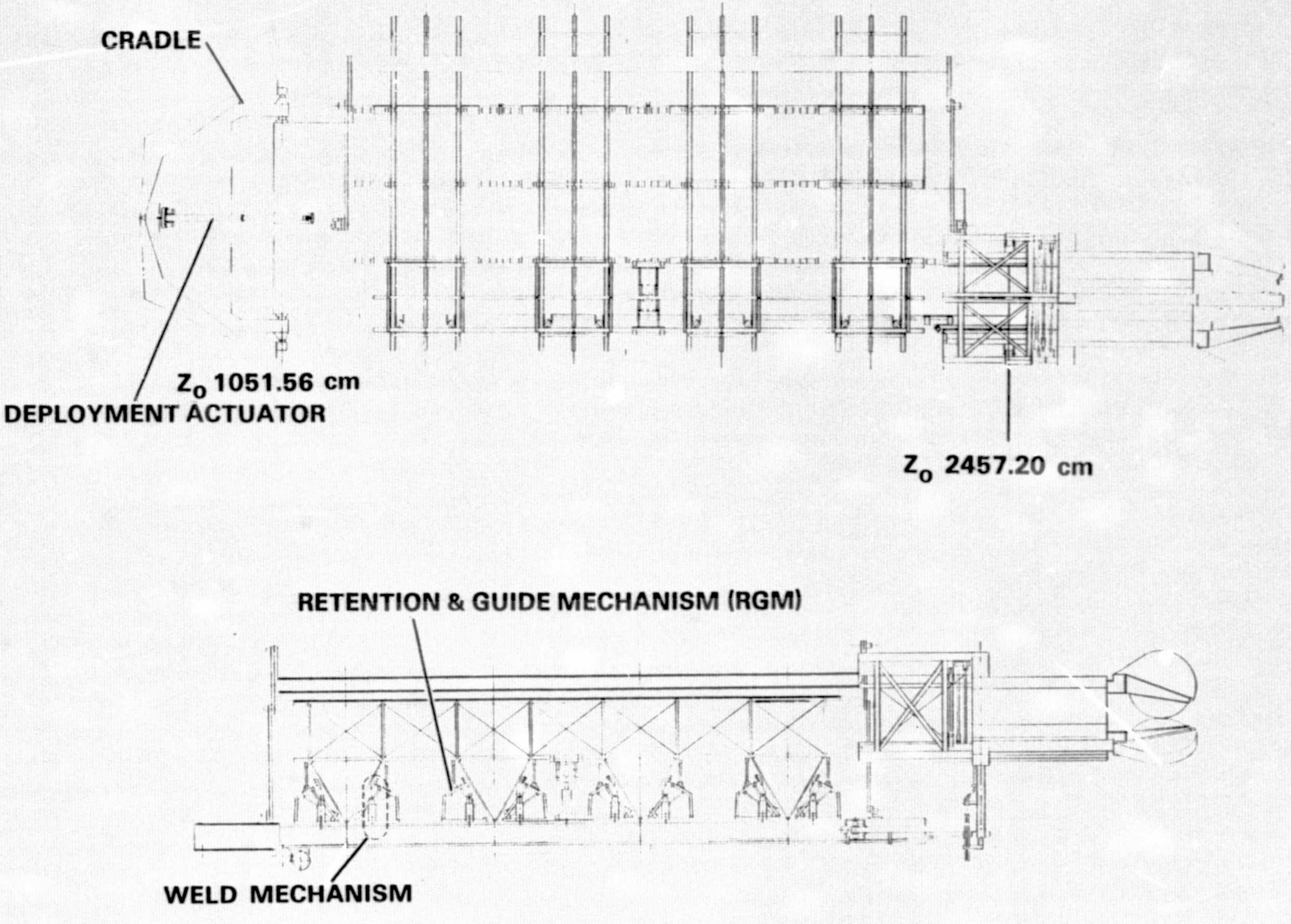
2. The cross beam advances to the next row of RGM's and the platform pauses.

3. The first row of RGM's is engaged and the second row retracts leaving the platform supported by the first and third row. The platform is advanced.

4. As the cross beam approaches the third row of RGM's the platform pauses. The second row is engaged and the third row retracted leaving the platform supported by the first and second row. The platform is advanced.

5. The third row of RGM's engages after the cross beam passes and the platform continues to retract until the next cross beam is encountered, at which time the step through process is repeated.

ASSEMBLY JIG DESIGN CONCEPT



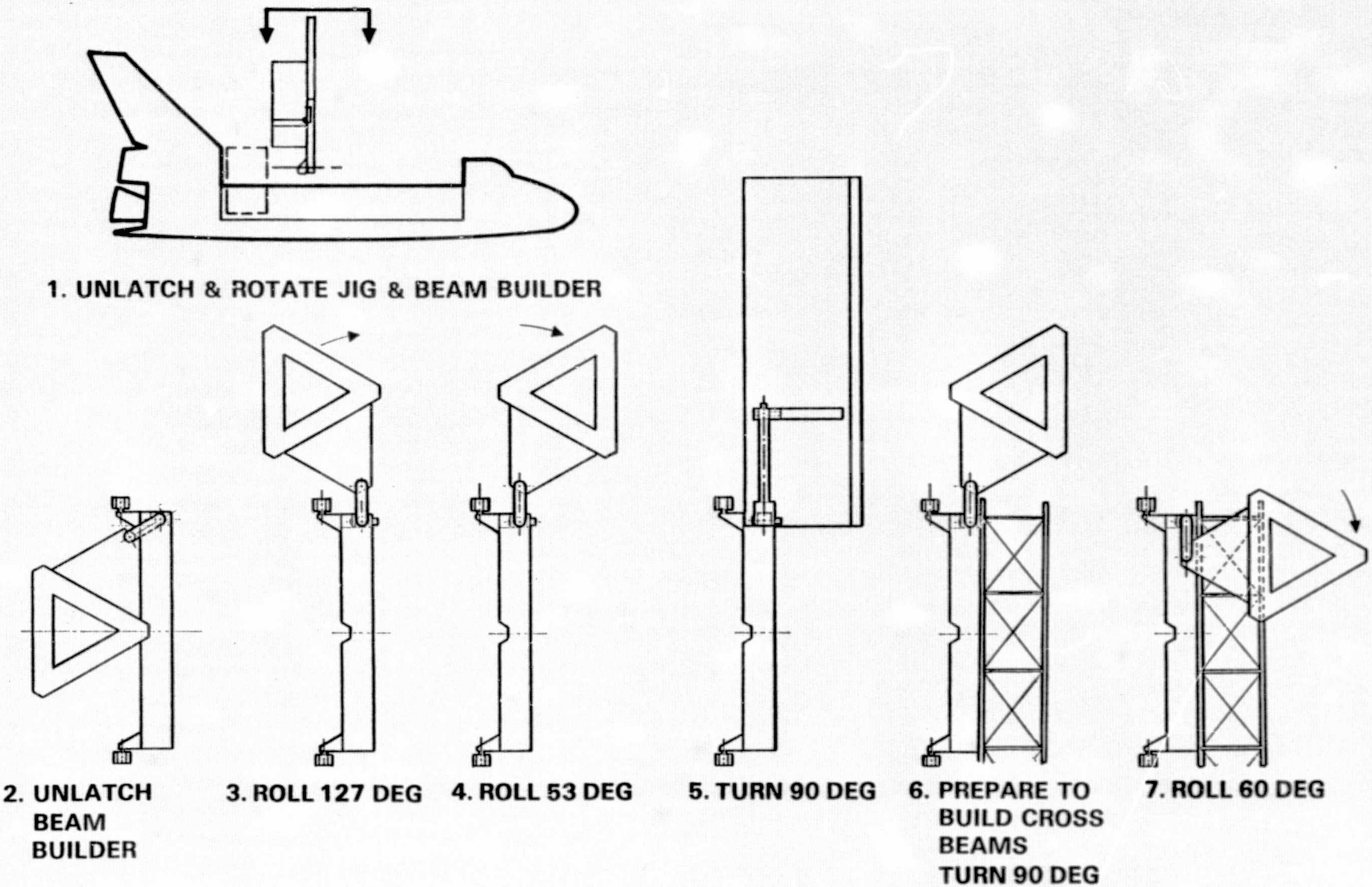
The assembly jig is deployed by unlatching the forward Z support pins and rotating the jig about an axle concentric with the aft X-Z trunion support pin.

When the longitudinal axis of the jig is parallel to the Z axis the jig is locked in position and the beam builder is unlatched for deployment.

Beam builder deployment and positioning is described as a series of operations by the roll and turn mechanism. The beam builder is rolled 180° to the orientation for longitudinal beam fabrication in two steps as shown in Steps 3 and 4. It is then turned 90° as shown in Step 5 to position the axis of the longitudinal beams normal to the longitudinal axis of the jig.

To reorient the beam builder for cross beam fabrication, it is first turned back 90°. The roll link then rotates 180° as the beam builder counter rotates 120° resulting in a net rotation of the beam builder of 60° and a lateral translation to the desired position.

TYPICAL JIG & BEAM BUILDER DEPLOYMENT SEQUENCE



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The beam builder positioning subsystem includes all mechanisms necessary to deploy and position the beam builder with respect to the assembly jig. The mechanisms concepts for this subsystem are described as follows:

A. The carriage mechanism travels along two round guide ways on four linear ball bearings. Dual drive redundancy is provided by two independent gear motors which operate pinion gears in a common spur gear rack. Each drive may be automatically disengaged through magnetic clutch mechanisms. The carriage body includes the support link for the turnarm and a fairlead clamp which secures the umbilicals to the carriage in such a way as to allow a pull force to be exerted on the umbilicals. The round guide ways are fastened to a machined support which in turn is fastened to the assembly jig structure.

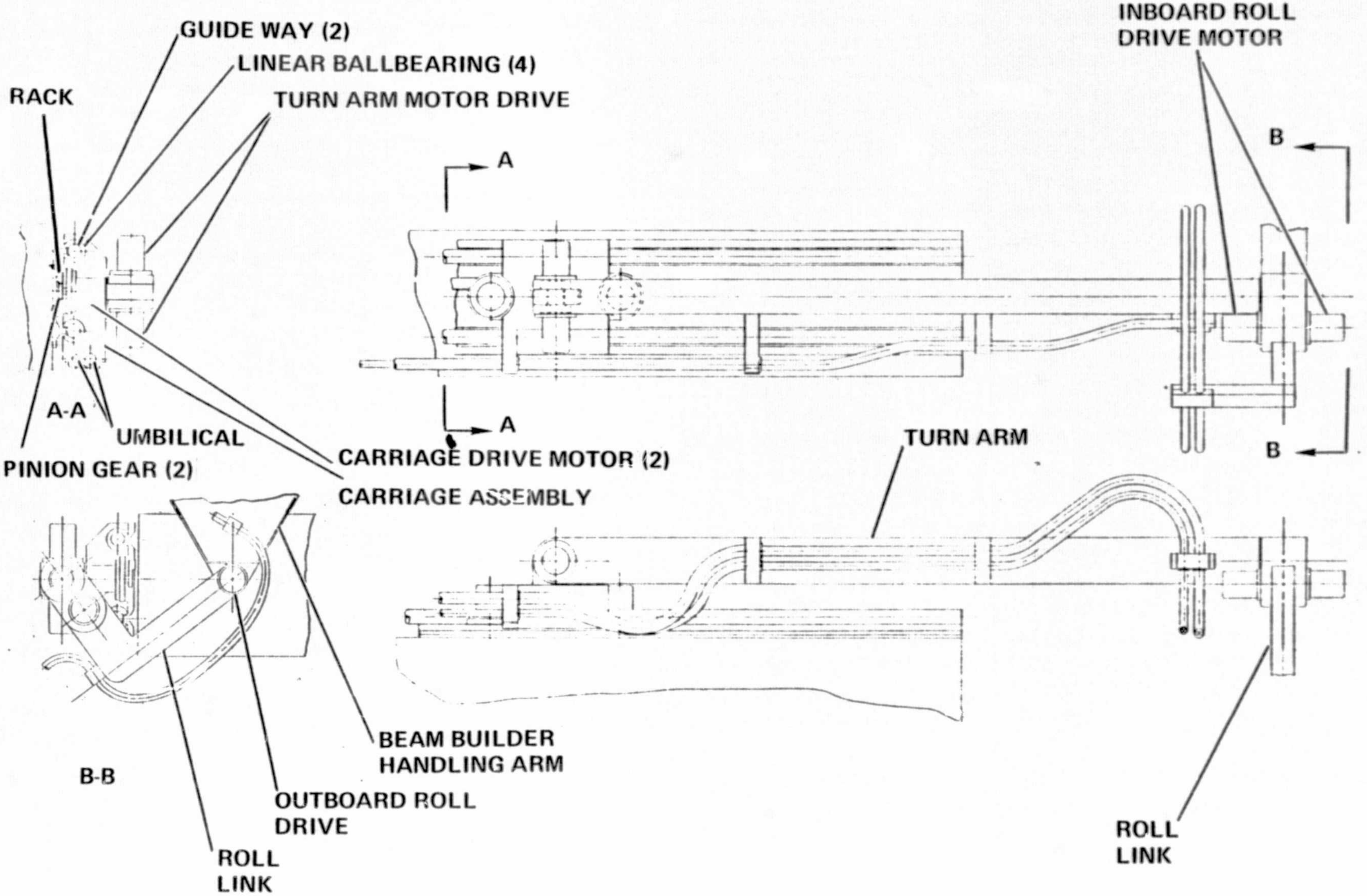
B. The turn arm mechanism rotates about a shaft which is keyed to the carriage support link. Dual drive redundancy is provided by two independent gear motors of the same design as the carriage drive motors. The motor shafts are splined or keyed inside the clevis shaft. Roller bearings are provided in both sides of the clevis. All bearings are compatible with maximum VRCS imposed loads; however, loads are minimized if VRCS is not activated during beam builder positioning operations.

The other end of the turn arm is a straight shaft about which the roll link rotates on roller bearings mounted inside the inboard end of the roll link.

Umbilical supports and clamps are mounted on the turn arm to provide cable loops about each axis of rotation in such a way as to prevent twisting of umbilicals as the beam builder is rotated and translated.

C. The roll link mechanism has an inboard and outboard rotating drive. The inboard roll drive has two redundant gear motors similar to the carriage drive motors. Each motor operates a spur gear which acts against a gear mounted on the turn arm shaft. The outboard drive has two similar motors which are keyed or splined to a clevis shaft mounted on the beam builder handling arm. Both sides of the outboard clevis are provided with roller bearings. An umbilical support and clamp are mounted on the roll link to provide cable loops about each axis of rotation.

BEAM BUILDER CARRIAGE AND ROLL/TURN MECHANISM



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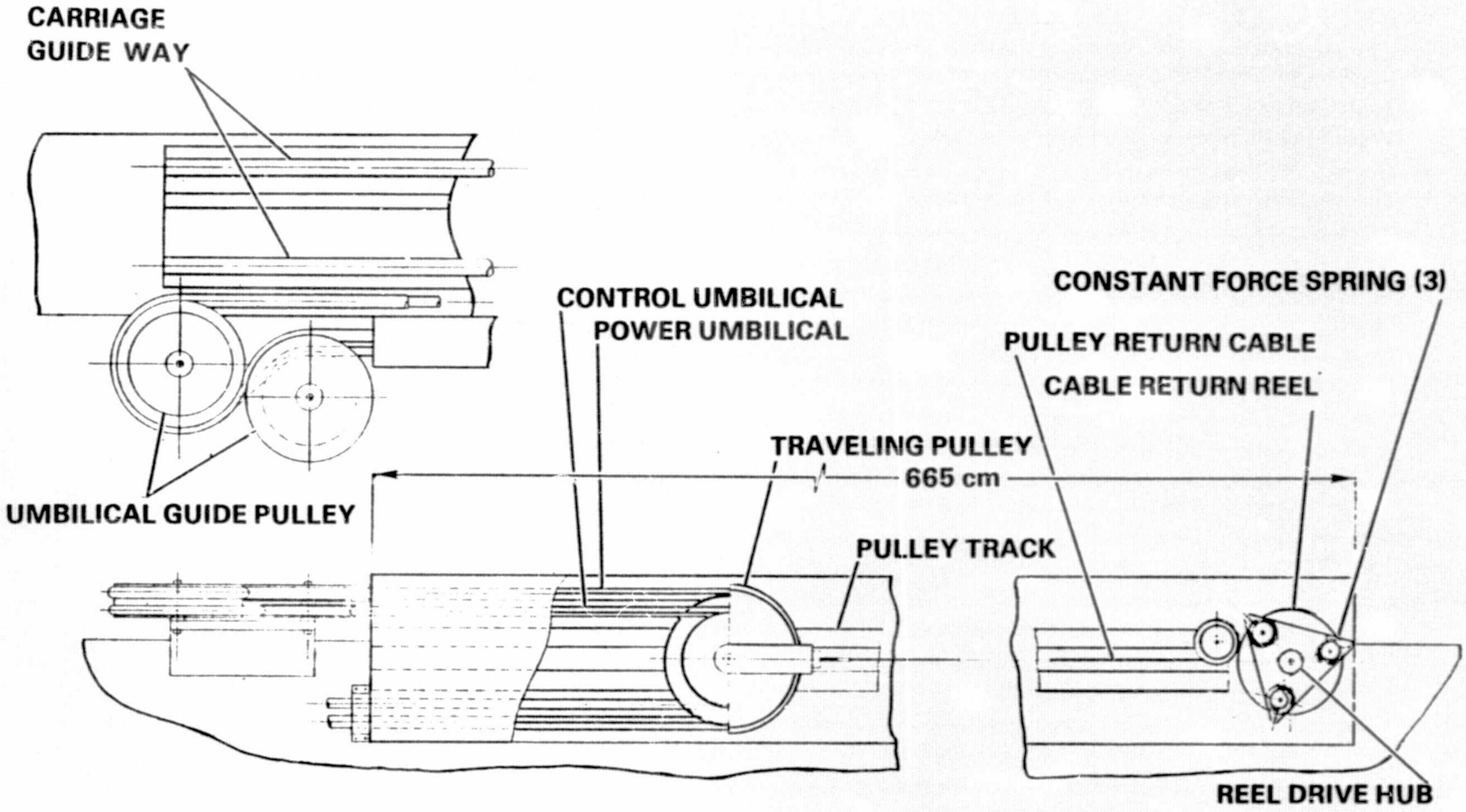
The umbilical handling mechanism employs a track guided traveling double pulley which is connected to a spring return reel. As the beam builder carriage moves up the jig it pulls on the power and control umbilicals which are routed over two guide pulleys. The pull force displaces the traveling pulley half the distance of the carriage travel. As the carriage returns the spring return reel retracts and the traveling pulley takes up the umbilical slack.

BEAM BUILDER UMBILICAL SLACK CONTROL MECHANISM



010288082J0276

A rigid latching coupler attaches the front end of the beam builder to the assembly jig. This coupler provides the necessary rigidity to prevent beam builder motion from adding significantly to beam deflection during beam manufacture.

The technique for hand-off of a beam from the beam builder to the RGM is also controlled by the latch and alignment functions as described below:

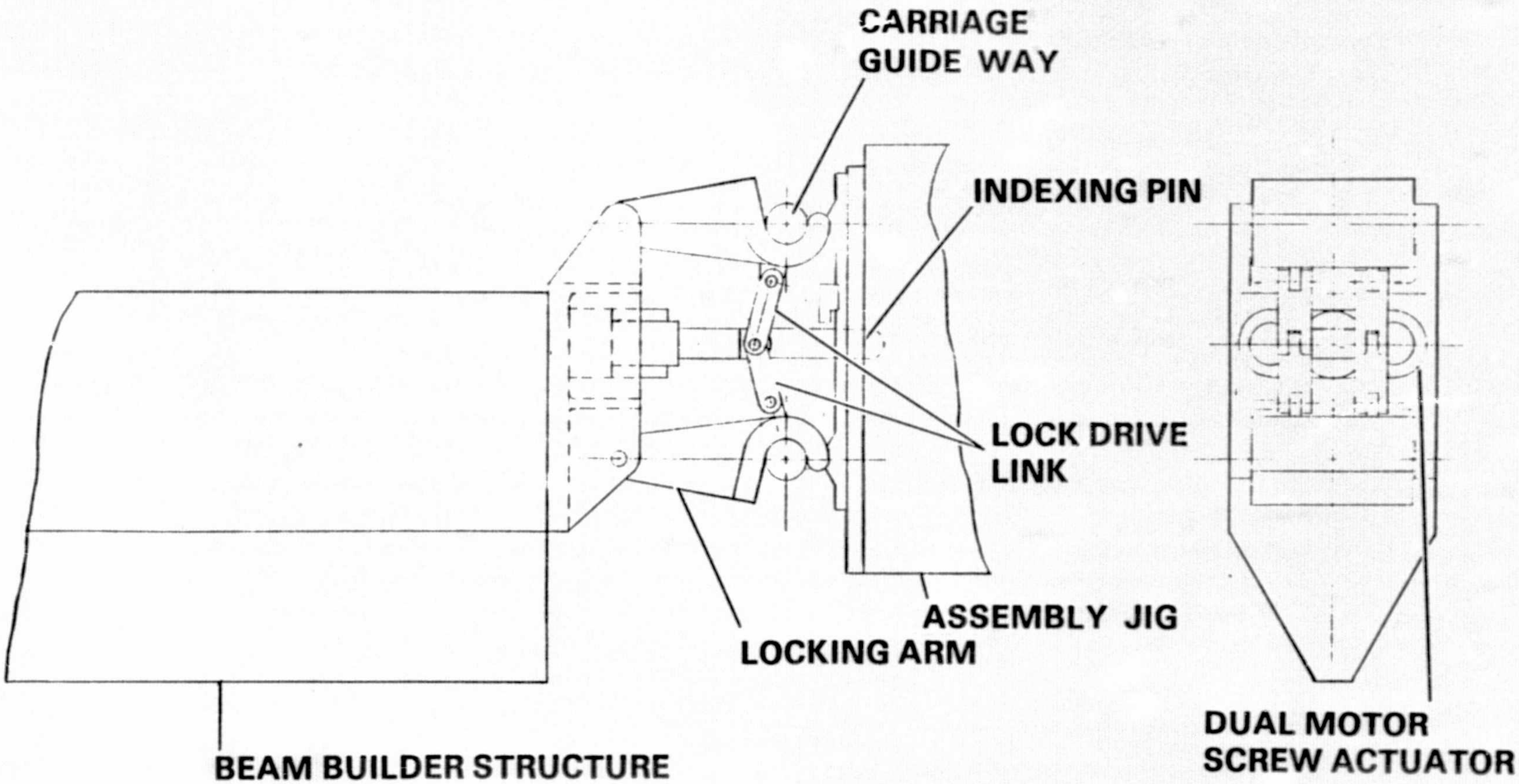
1. The beam builder is closely aligned with the center of the RGM's by an index pin which is driven by the latch mechanism into an indexing hole in the side of the jig as shown. The latch mechanism engages the carriage guide ways which assures angular alignment with the RGM.

2. The vertical alignment of the beam with the PDM is biased during machine set-up and alignment to ensure a small (1 to 2 mm) clearance will exist during beam fabrication between the drive rollers and the beam.

3. When the beam is complete and ready for hand-off the two RGM's farthest from the beam builder are engaged. The span between the beam builder and the RGM's allows sufficient deflection to take place such that the gap between the drive rollers and the beam can be closed without damaging the beam.

4. The beam is severed from the beam builder by the cutoff mechanisms before engaging the third RGM. The beam builder is unlatched and translated to the next position leaving the beam retained by the RGM's.

BEAM BUILDER LATCH & ALIGNMENT MECHANISM



010288082J0274

The longitudinal beam handling subsystem includes all the mechanisms required to retain and position the longitudinal beams on the assembly jig. These mechanisms are described below.

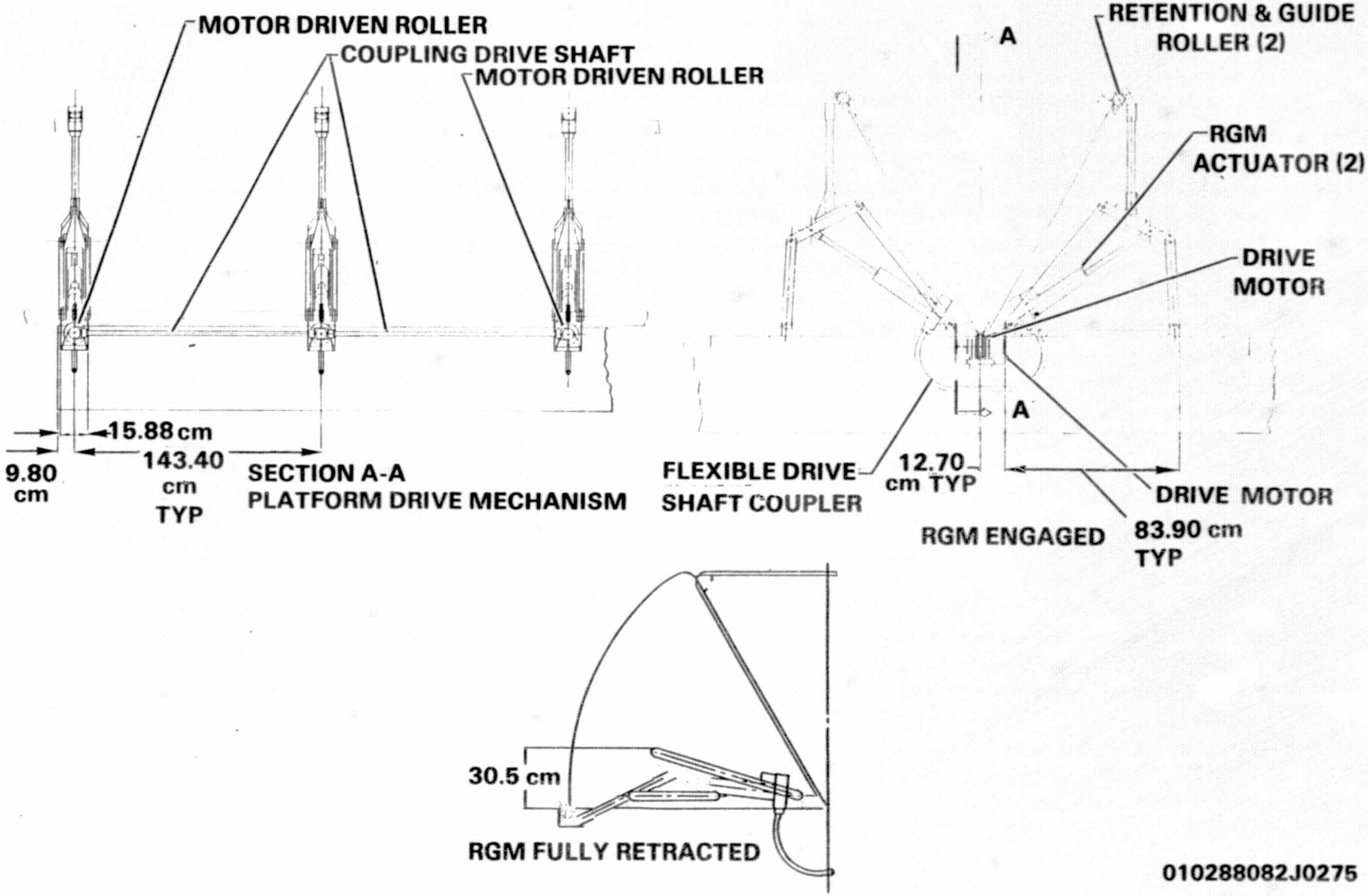
A. The Retention and Guide Mechanism (RGM) clamps each longitudinal beam to the jig and guides the beam as it is translated by the Platform Drive Mechanism (PDM). The twelve RGM's consist of a pair of rollers each mounted on a semi-rigid shaft attached to a four bar linkage mechanism. Each four bar linkage is driven by a linear screw drive actuator. Each actuator has a single motor drive which can be automatically disengaged by a magnetic dutch mechanism. Each pair of actuators id drive coupled through a flexible drive shaft. This arrangement provides dual motor drive redundancy for each RGM.

The RGM's are fully retracted for flight and platform separation. During step through operation the RGM's are partially retracted in sequence to clear the cross beams as they pass over.

B. The PDM acts as a friction holding device to prevent beam translation on the jig when clamped on the RGM's. Three friction drive wheels apply drive force to each longitudinal beam such that the beams can be individually positioned or driven in unison. Platform mating guides (not shown) are required to guide the platform into the PDM's during platform capture and re-mating operations.

Dual motor drive redundancy is provided by coupling three rollers to a common drive shaft with motor drive input to each end roller. Either motor can be automatically disengaged by a clutch mechanism, should the other motor fail.

LONGITUDINAL BEAM HANDLING MECHANISMS



010288082J0275

The cross beam handling subsystem is comprised of the cross beam positioner mechanism. This device is driven laterally along a short track to a preset position directly under the center of the finished cross beam as it is supported in the beam builder. The handler arm mechanism is raised to a preset position by a linear screw drive actuator. The handler arms are engaged to grasp the cross beam on two caps by a second screw drive actuator. After the beam is severed from the beam builder the positioner is driven laterally to a preset position which aligns the cross beam with the longitudinal beam cross members. The linear screw drive actuator then lowers the beam into contact with the longitudinal beams. When the first row of cap to cap weld joints is complete the second screw drive actuator retracts the handler arms below the cross beam and the platform is advanced to the next weld station. All positioner/handler drives are dual motor redundant.

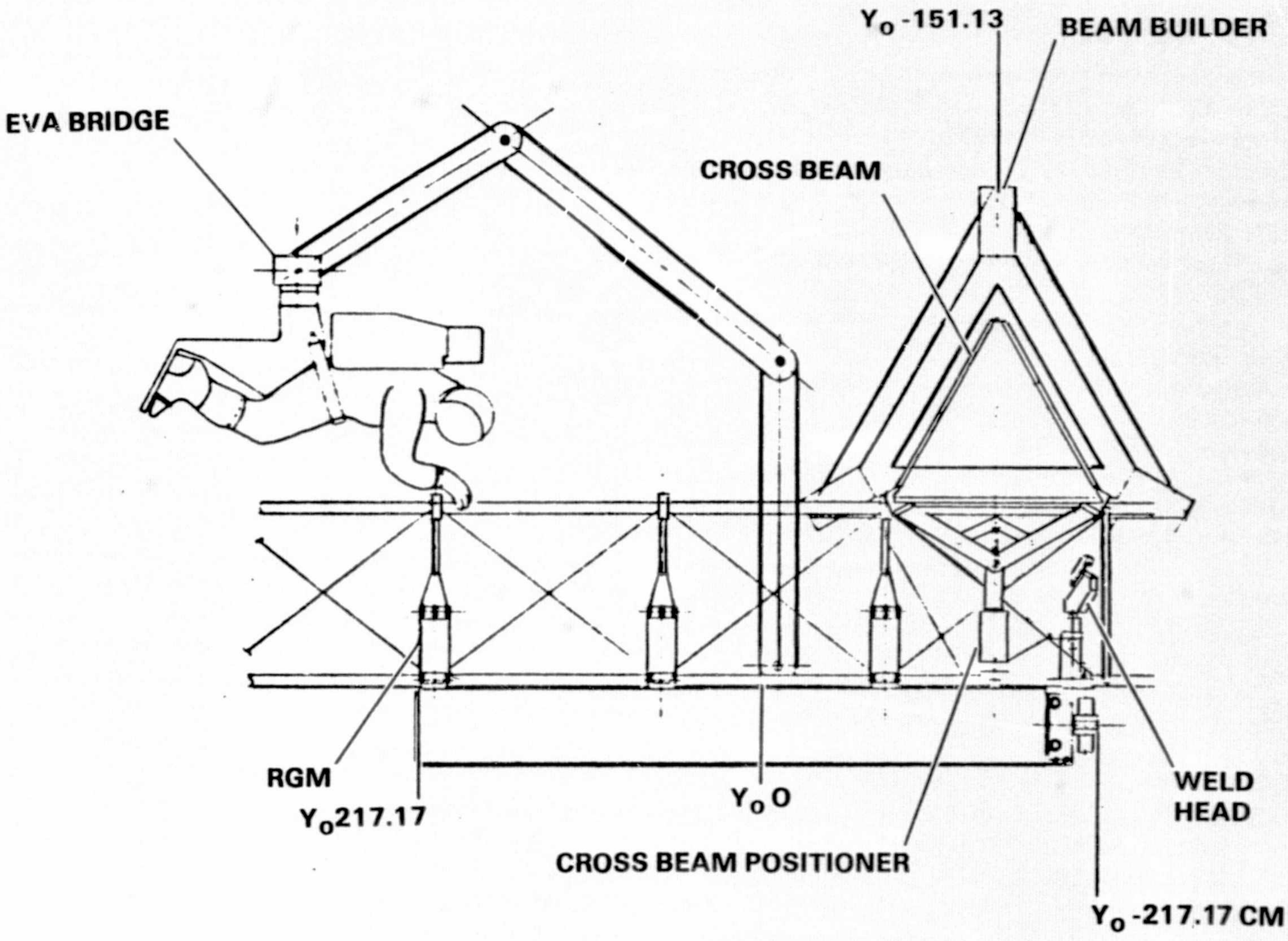
The EVA support subsystem includes all mechanisms and controls required to aid EVA personnel in accomplishing platform equipment installation tasks. The principal aid is the EVA bridge mechanism. This device allows one man to position and support his body over any position on the platform within the reach of the bridge mechanism.

The two control arm assemblies have synchronized motor drives for each link. These control arms move the bridge up and down as well as longitudinally back and forth. A carriage mechanism traverses the bridge to allow lateral positioning of the man restrained by the traveling chair. The chair provides foot restraints as well as body restraints to allow a neutral body position to be maintained.

The chair is equipped with a local control panel to permit the man to manually control his position with respect to the platform. Safety position limit sensors prevent inadvertent collision of the man with the platform. The chair position can also be manually controlled from a second control station located in the payload bay on the end of the assembly jig.

The traveling chair is detached and stowed for flight to allow the EVA bridge to lie flat on the face of the jig.

PLATFORM CONSTRUCTION & EQUIPMENT
INSTALLATION PROCESSES



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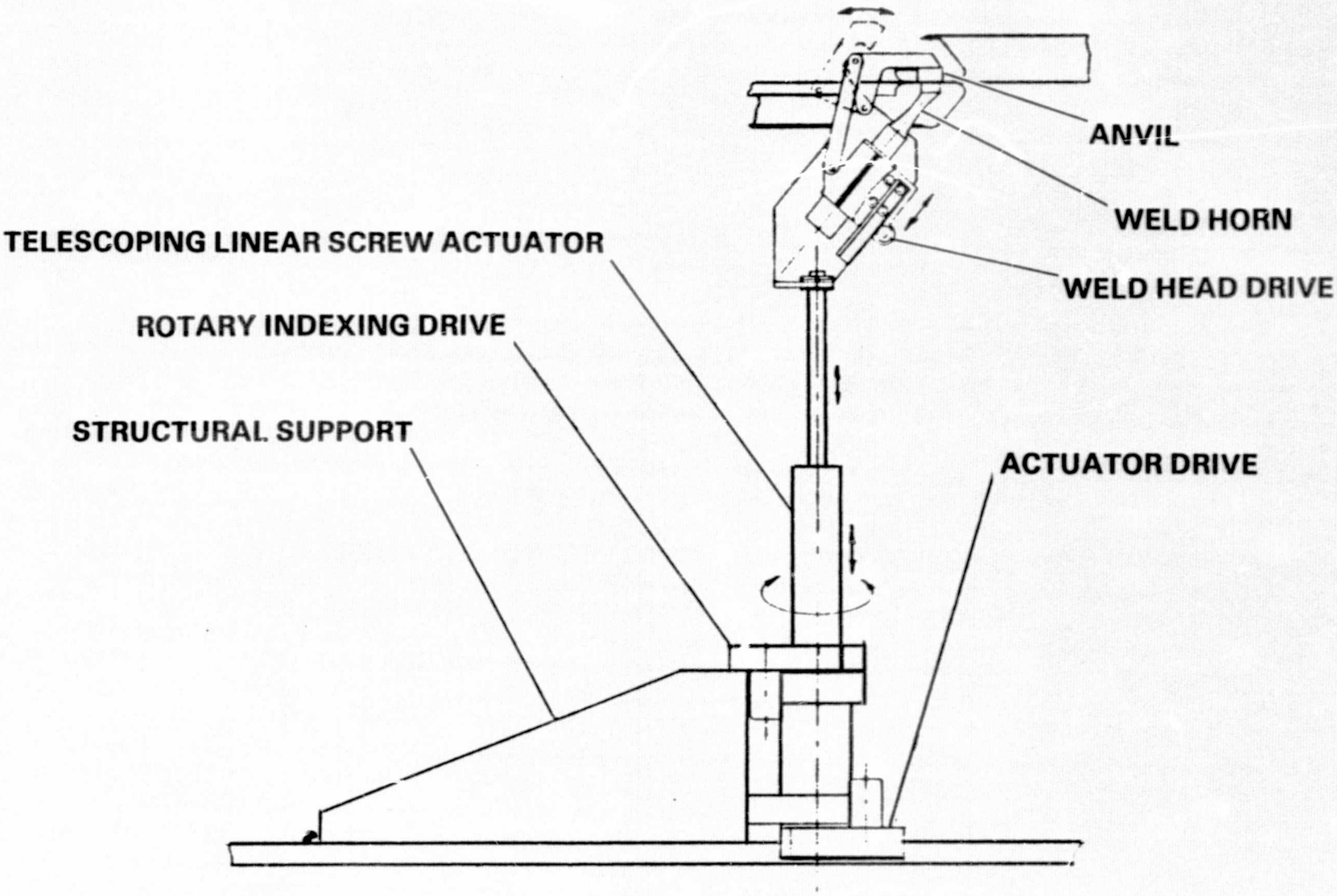
With the cross beam positioned on the longitudinal beams by the assembly jig, the weld heads are aligned with the access zones between the tension cords on the beams. Each weld head is raised to a preset height and the weld head engagement drive is activated. The weld horn is inserted at an angle into the lower cap while a drive linkage rotates the weld anvil into the upper cap until the horn and anvil apply contact pressure to the weld zone. On application of the proper contact pressure the weld horn is activated to initiate the weld, then deactivated for a brief cooling period. The weld head engagement drive is reversed and the extend/retract drive lowers the weld head clear of the beams.

The platform then advances 1m as the weld heads are rotated 90^o. The next row of welds is then completed in the same sequence then the weld heads are indexed back 90^o as the platform advances to the next cross beam installation station. The time estimated for making the 16 weld joints is 100 seconds.

CROSS-BEAM TO LONGITUDINAL BEAM ULTRASONIC WELDING MECHANISM



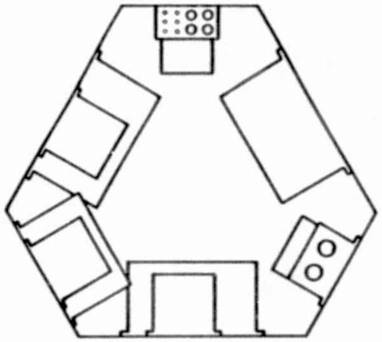
01028808J0273

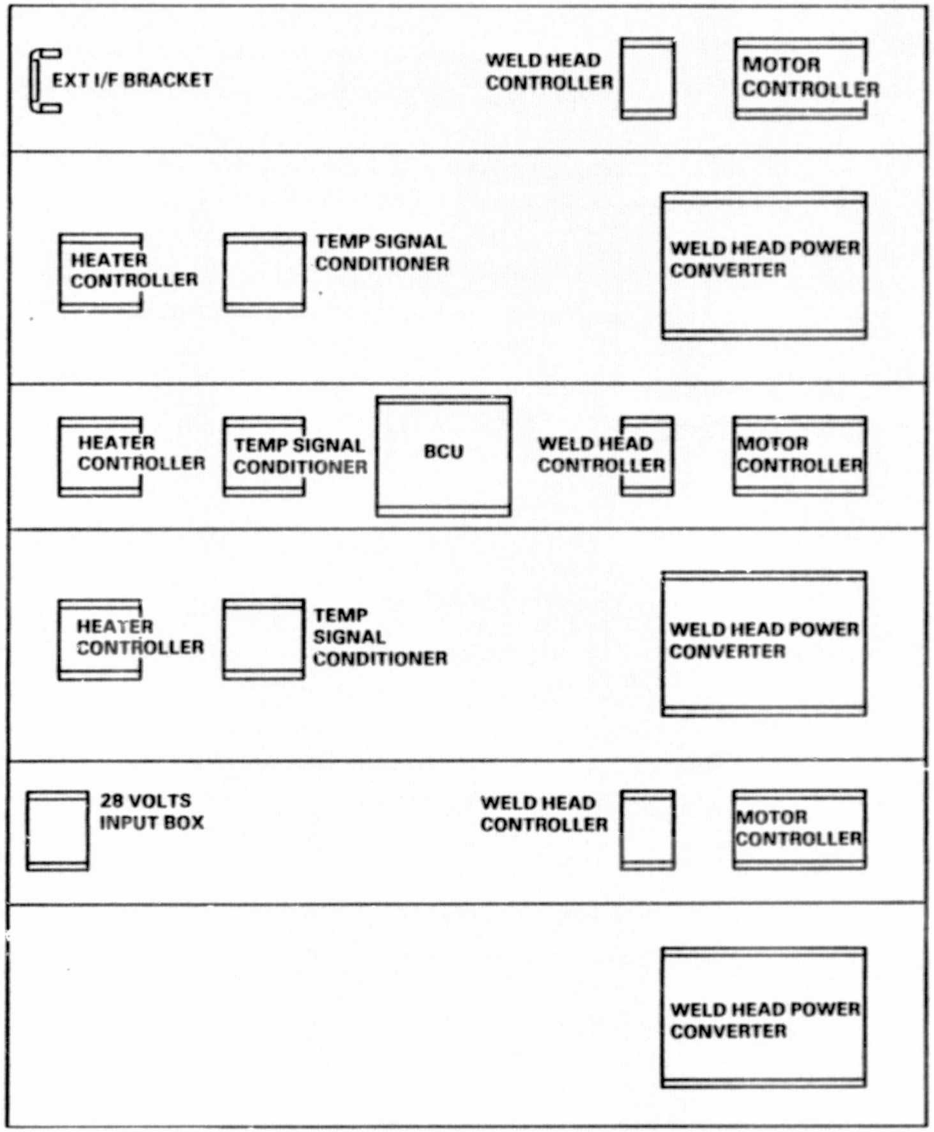
Alternate packaging/arrangement of beam builder avionics on and within the beam builder were investigated. The figure on the facing page represents the baseline configuration. Other configurations investigated included: a) slide in carriage, and b) side panel entry concepts. In the baseline configuration shown the avionics are mounted to the walls of the tunnel space available within the beam builder forming section support structure.

The end view is taken from the cap material storage canister end of the structure. Package arrangement about the periphery of the tunnel is indicated in this view.

Packages are distributed over the full length of five of the six surfaces of the tunnel. The sixth surface is clear overall of its length except at the farthest end. The flat surface development of the tunnel surfaces, illustrates the distribution of the packages. The development starts (top of figure) with the surface supporting the external interface bracket, and continues counter-clockwise around the tunnel to the surface supporting the external 28 volts input box. The bottom-most surface illustrated here is that which was earlier noted as clear over most of its length. This surface provides for access to all packages and their related harnessing.

CONTROL AVIONICS PACKAGING CONFIGURATION





- Beam builder avionics packaged within central core
- Alternative concept evaluated
- Preliminary component & unit sizing determined

010288082J0303

The beam builder avionics packages and associated interconnect diagram are shown on the facing page. These consist of the following quantities and functions:

The external interface bracket provides for entry to the beam builder of electrical control and monitor functions from the Shuttle Orbiter mission specialist station.

The weld head controller package works in conjunction with its associated weld head power converter packages to active and monitor weld head operation. Each two-package set supports two welders.

The motor controller package provides drive circuits for operation of applicable brushless d.c. and stepper drive motors. Each package can support up to twelve motors.

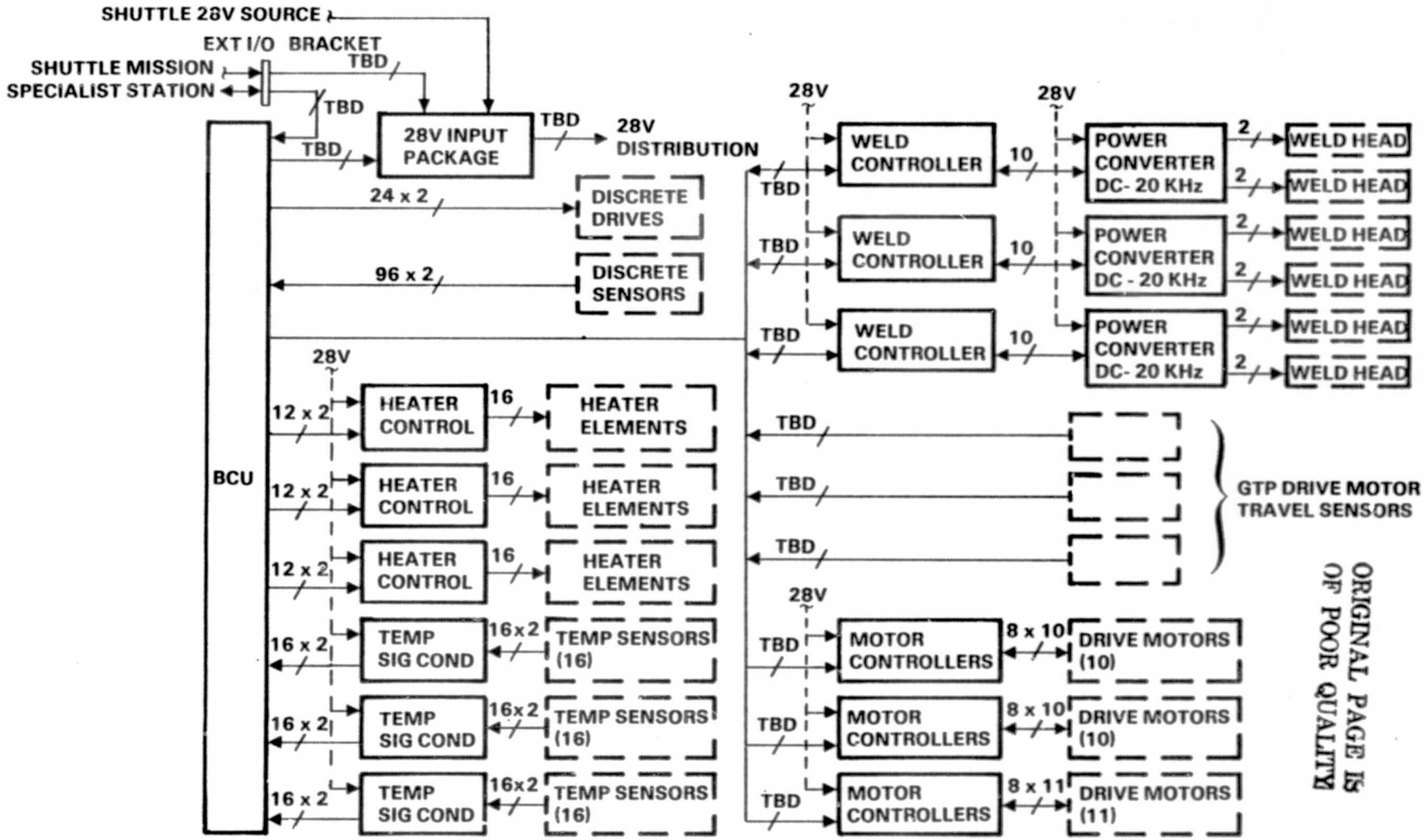
Each heater control package provides voltage regulation and power switching circuits to support a related cap member's infrared and ambient temperature sensors.

The 28 volts input box provides an input interface and transfer switch capability for distribution to beam builder elements of Orbiter-provided 28 volts d.c. excitation power.

The BCU consists of the system processor, supporting memory, and input/output (I/O) elements for data transfer. This unit controls the operation of all other packages described above. It also provides for monitoring of all discrete sensors, and for activation of all discrete control functions (solenoids, etc.). Finally, it provides the logical interface with the Shuttle Orbiter mission specialist station.

BEAM BUILDER AVIONICS INTERCONNECT DIAGRAM

GENERAL DYNAMICS
Convair Division



ORIGINAL PAGE IS OF POOR QUALITY

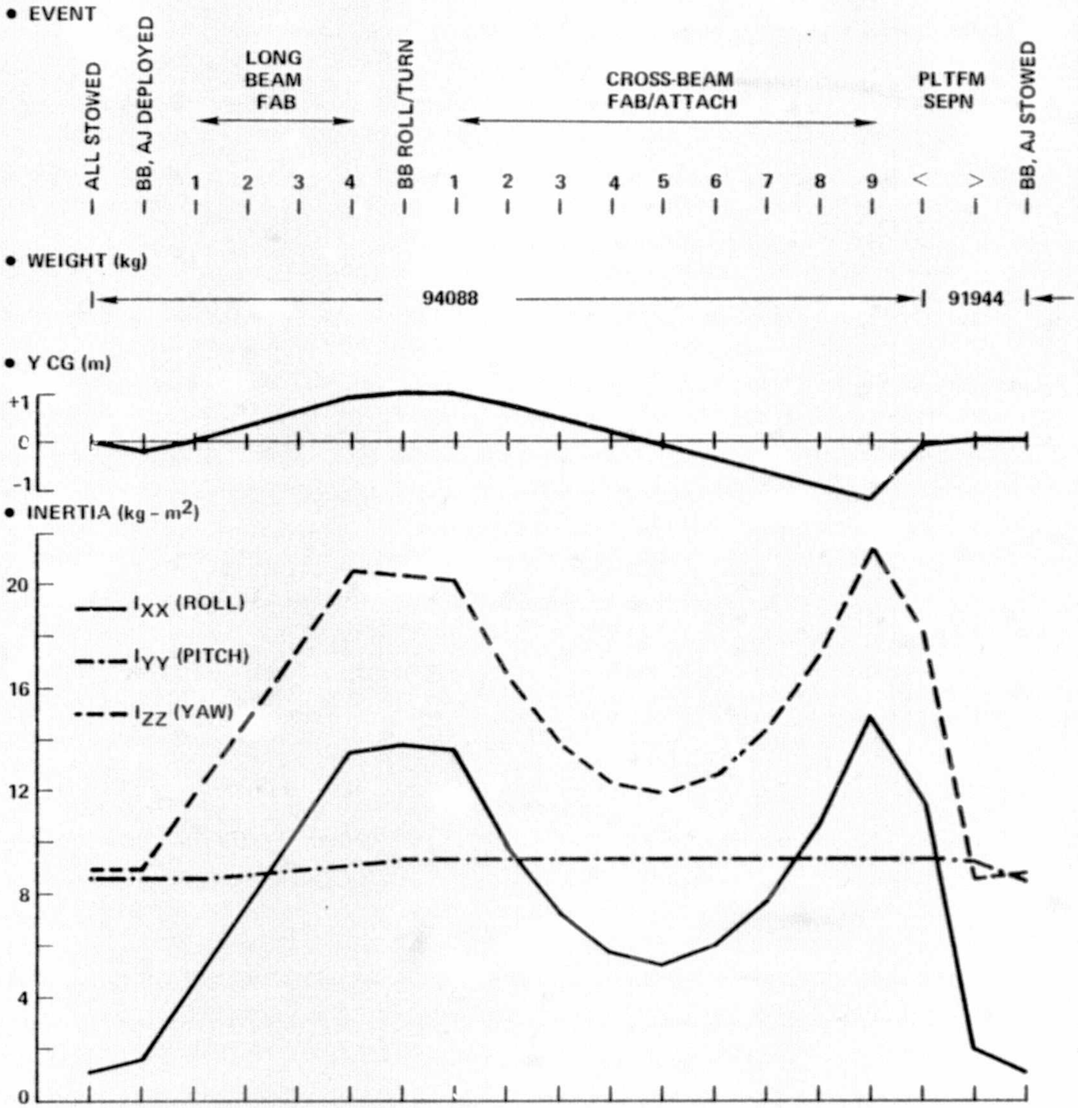
010288082J0304

Final mass properties have been developed from the completed preliminary designs of the SCAFE system elements. Major system elements have been coded as indicated in the arrangement sketch and their total weight and center of gravity coordinates are tabulated below.

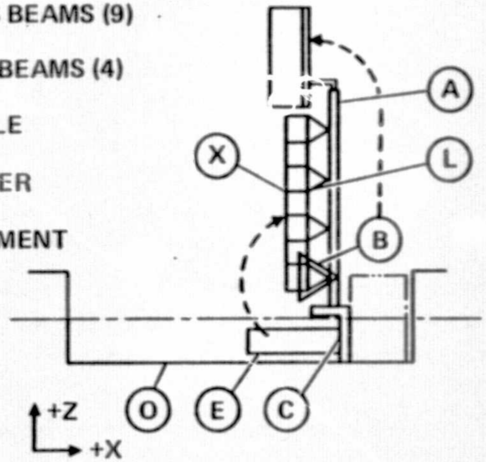
In addition the system mass properties were determined for each discrete-configuration mission event from post-boost stowed to pre-entry stowed. This data is also shown. Lateral (± Y) center of gravity and all moment of inertia are plotted to highlight significant variations during the nominal mission. Inertia cross-overs indicate the change of gravity-gradient attitude of the total system and are discussed on a later chart in conjunction with fabrication orientation selection.

FINAL MASS PROPERTIES

- **SYSTEM ELEMENTS**



- **TOTAL SYSTEM vs MISSION EVENT**
- **ARRANGEMENT**
  - (A) ASSEMBLY JIG
  - (B) BEAM BUILDER
  - (X) CROSS BEAMS (9)
  - (L) LONG BEAMS (4)
  - (C) CRADLE
  - (O) ORBITER
  - (E) EQUIPMENT



- **CHARACTERISTICS***

ITEM	W (kg)	CG (m) X	CG (m) Y	CG (m) Z
A	3,372	28.8	0.0	17.2
B	2,645	27.1	-1.5	26.0
X	108	27.2	-99.1	16.8
L	889	28.0	-97.5	16.7
C	1,626	28.6	0.0	8.9
E	1,147	28.1	-32.5	16.8
O	82,424	28.8	0.0	9.6

*FABRICATION, ASSEMBLY, EQUIPMENT INSTALLATION COMPLETE

01028082J0313

In the preliminary space heating analysis, a highly conservative approach involving long duration shadowing of one beam cap by another was taken. However, sustained cap to cap shadowing cannot occur in the presence of normal on-orbit motions and structural deflections.

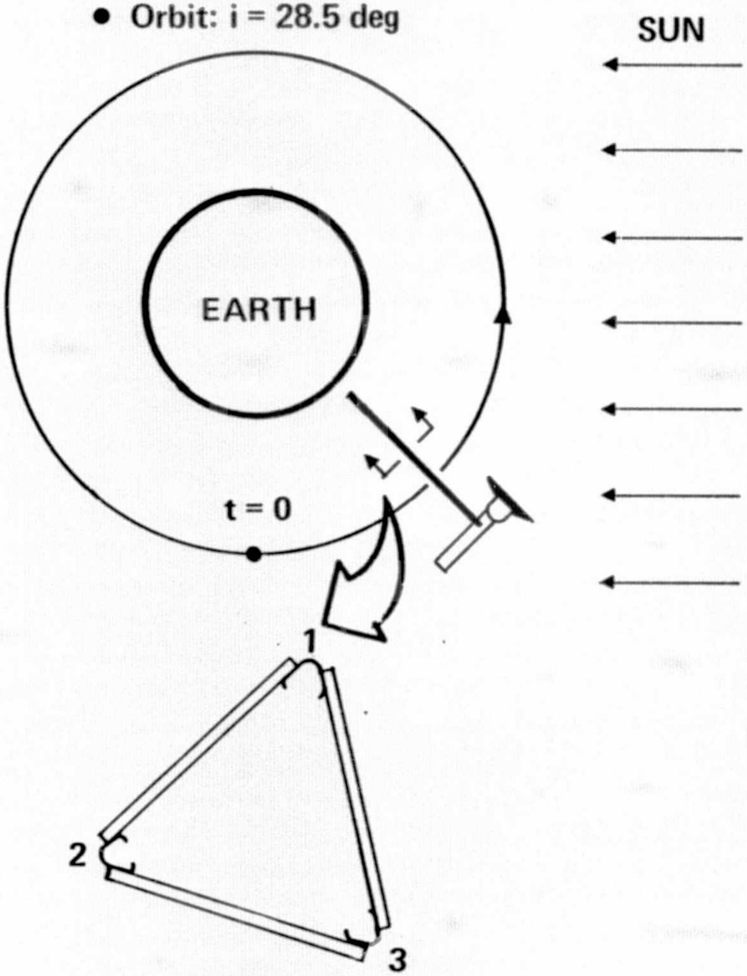
Consequently, a final analysis was conducted assuming the baseline 9:00 AM ETR launch on 21 June 1982 to a 300 nautical mile orbit (period 95.6 minutes) with a 28.5° inclination to the equator. The estimated pitch, yaw and roll oscillations of the shuttle/beam configuration, as developed in the stability and control analysis, were also included. The orbit period begins ($t = 0$) at the terminator moving eastward for the final analysis while for the preliminary analysis the orbit period begins on the backside of the earth at the midnight position. For the calculation of radiation view factors, one bay length of beam was modeled in great detail, including cross members plus an increased accuracy in the modeling of the caps. The results were again extrapolated for the 200 meter beam model which included the shadowing effects of the shuttle.

Increased modeling detail in the final analysis also enables a more accurate calculation of local temperatures across the beam caps. Local cap temperatures will reach a peak value of approximately 265.0°K with an approximate ΔT of 40.0°K across the cap at $t = 49$ minutes. Local minimum cap temperatures achieve a value of approximately 170.0°K with a ΔT of approximately 65°K across the cap at $t = 82.5$ minutes.

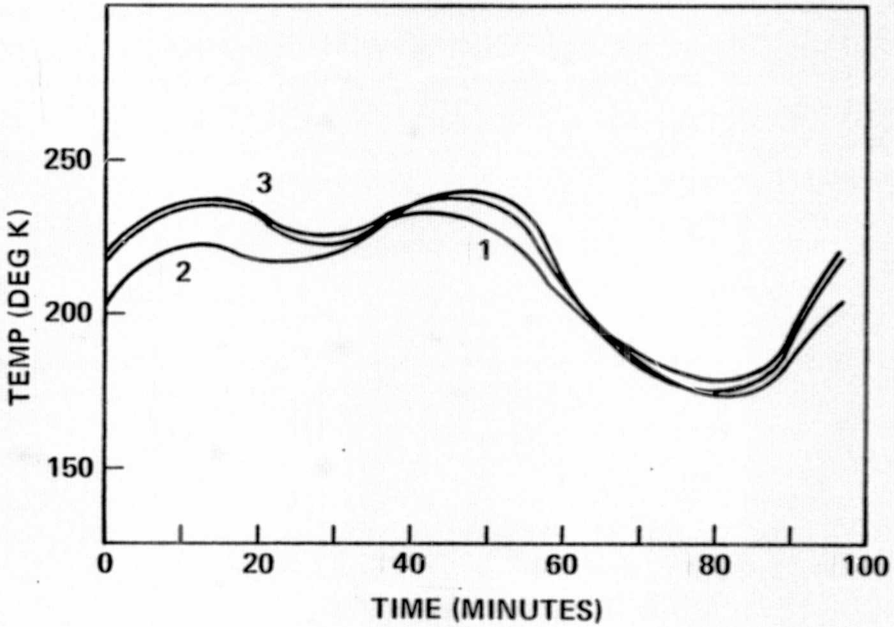
The final space heating analysis reveals a much smaller temperature difference cap to cap across the beam, which should result in lower beam thermal loading and distortion than projected from the preliminary analysis.

UPDATED SPACE HEATING ANALYSIS

- MODEL
  - Single 200m beam
  - Idealized shuttle
  - Earth-fixed orientation
  - Orbit: i = 28.5 deg



- RESULTS
  - α/ϵ = 0.34/0.89
  - Orbit period = 95.6 minutes



01028082J0298

A worst case cap thermal condition was analyzed to determine beam tip end deflection.

The maximum thermal distortion occurs, as shown for Beam 1, when sustained cap-to-cap shadowing results from two caps remaining coplanar with incident space heating. Combining this with the most severe shuttle shadowing effect results in maximum cap to cap temperature gradients.

Assuming one beam (200 m) attached to the Orbiter, a finite element model was developed using beam elements for the caps and posts and rod elements for the diagonals.

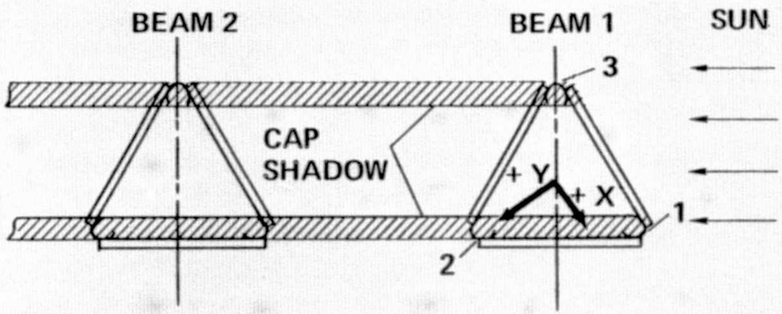
The temperature distribution along the length of the three caps at t = 23.9 minutes was input as grid temperatures.

The resulting tip displacements and maximum internal beam loads are tabulated. In spite of their ultra conservative derivation, these loads are still considerably lower than the maximum beam loads addressed on an earlier chart.

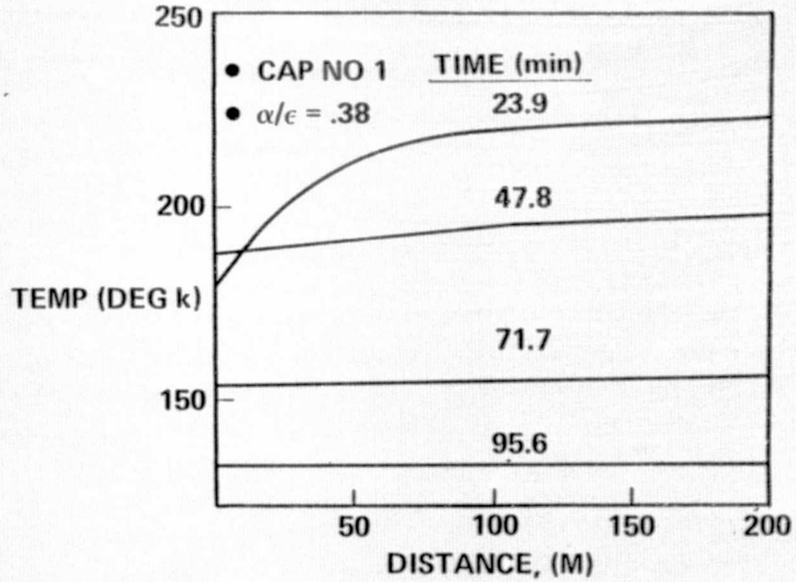
The impact of the computed deflection on inter-beam clearance is also shown in conjunction with previously presented clearance loss due to dynamic effects.

THERMAL DISTORTION CONSIDERATIONS

- BEAM SHADOW



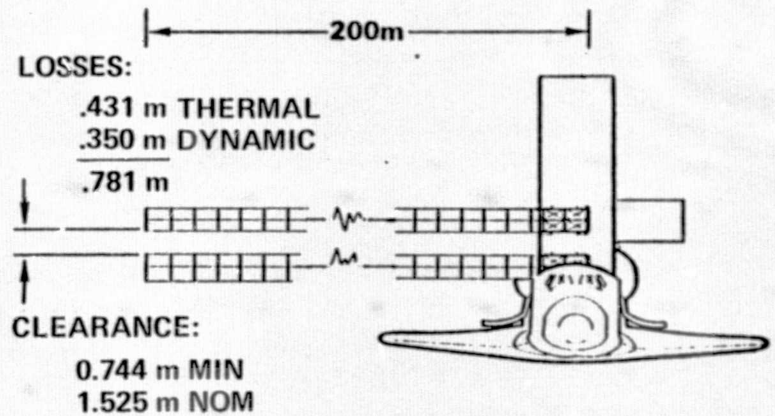
- ORBITER SHADOW



- STRUCTURAL RESPONSE

MODEL	LOADS	DISPLACEMENTS, m
• BEAM NO 1 • L = 200m • FINITE ELEMENTS: CAPS, POST: = BEAMS CORDS: = RODS • TEMP VS L t = 23.9 MIN	CAP: P = –77.0 N M = 0.41 Nm POST: P = 93.4 N M = 0.06 Nm CORD: P = 53.8 N	δ_x = –0.113 δ_y = –0.432 m δ_z = 0.004 m δ_{12} = 0.431 m

- CLEARANCE IMPACT

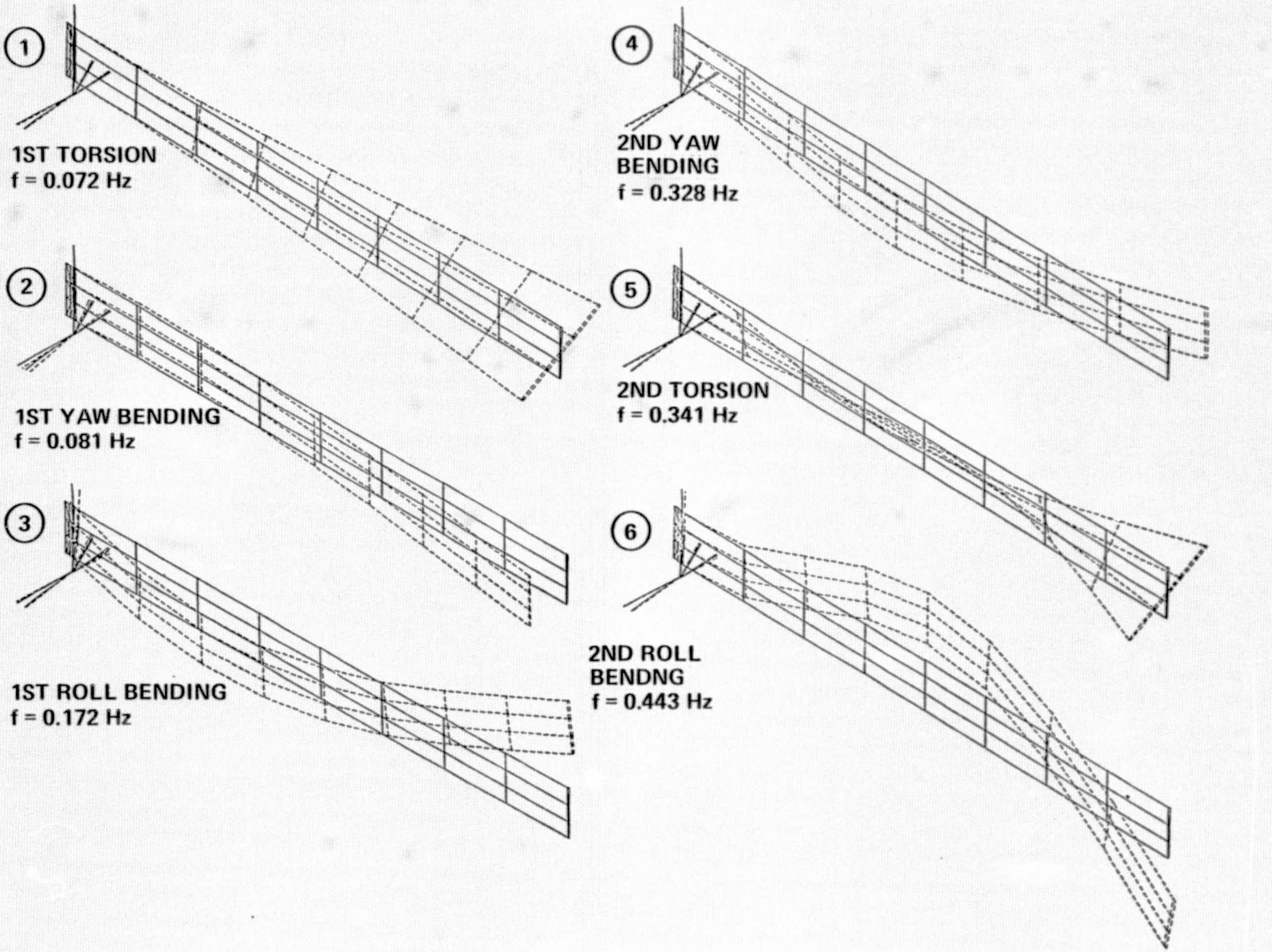


For the purpose of computing free-free mode shapes and frequencies, a previously developed Orbiter/single beam math model was expanded to include the four longitudinal beams and the nine cross beams. Each cross beam was divided into three segments. Each longitudinal beam was attached to the assembly jig at three points. This attachment is stiffer than the two point attachment used previously for a single beam. To determine the deflection at the VRCS thrusters, rigid beams were run from each thruster to the Orbiter c.g.

Rigid body and elastic modes were computed. The table below provides a list of the frequencies and a brief description of the predominate motion associated with each mode. The modes encompass platform bending, torsion and longitudinal motion. Shapes of the first six free-free elastic modes are plotted on the facing chart. The undeflected structure is shown by solid lines and the deflected structure by dashed lines. All fourteen elastic plus the six rigid body modes were used in the response analyses, discussed on the following chart.

Mode No.	Frequency, Hz	Period, Sec	Description
1	.07201	13.887	1st Torsion
2	.08107	12.335	1st Yaw Bending
3	.17204	5.8125	1st Roll Bending
4	.32802	3.0486	2nd Yaw Bending
5	.34095	2.9330	2nd Torsion
6	.44294	2.2576	2nd Roll Bending
7	.87626	1.1412	3rd Torsion
8	.87642	1.1410	3rd Yaw Bending
9	1.0811	.92498	3rd Roll Bending
10	1.1547	.86605	1st Longitudinal
11	1.6386	.61027	4th Torsion
12	1.6567	.60360	4th Yaw Bending
13	1.9020	.50455	4th Roll Bending
14	2.5972	.38504	5th Torsion

PLATFORM/ORBITER MODES



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Transient analyses were conducted to determine the platform tip elastic responses and internal loads due to a firing of the VRCS thrusters. The results are conservative since they are based on a duty cycle which maintains an attitude of ±1° in all three axes. Thruster combinations which produce Orbiter yaw, roll and pitch were used in three separate analyses. A complete VRCS duty cycle was considered in each case. No attempt was made to adjust successive pulse start times to minimize response.

Typical platform tip displacement and acceleration time histories due to a single cycle of yaw pulses are shown. The maximum tip responses for all three types of pulses are also tabulated. Beam 1 is the lower (nearest Orbiter) beam and beam 4 is the upper beam. Difference refers to the difference in response between beam 1 and 4. The platform is relatively stiff in the vertical direction compared to the fore and aft direction. The time history response plots illustrate the effect of starting time of the negative yaw pulse, which starts at 206 sec. If the pulse started a half cycle (6 sec.) sooner or later a cancelling effect would occur. The same principle applies to succeeding pulse cycles.

The maximum loads developed in each of the four main beams were determined as were the maximum moment and shear developed at two beam intersections. The largest of these values are also shown.

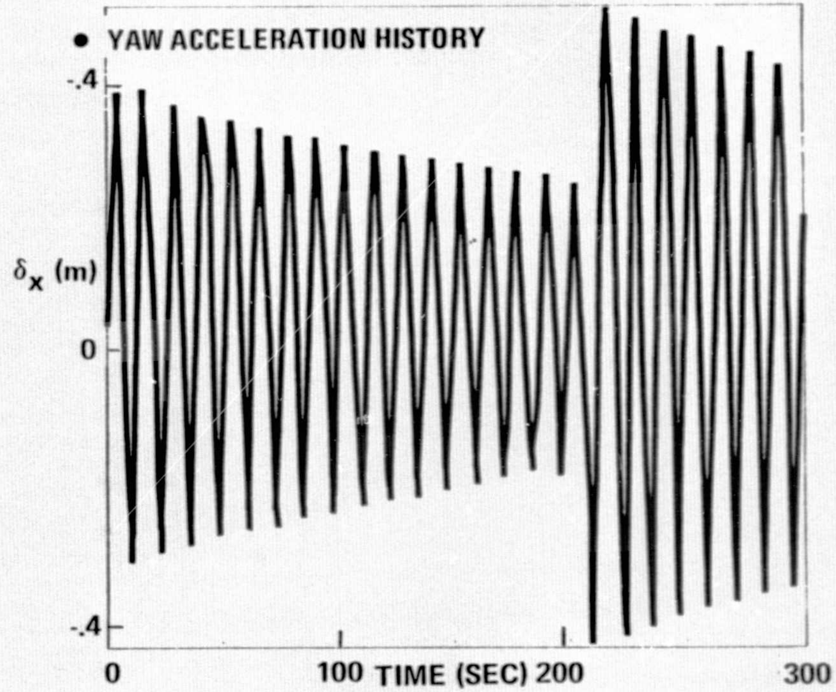
PLATFORM DYNAMIC RESPONSE

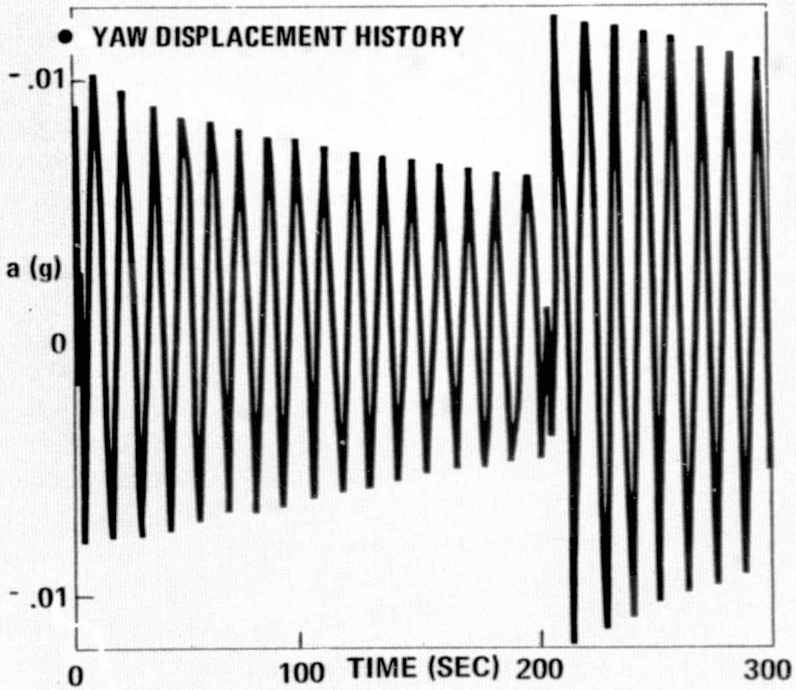
- ORBITER – ATTACHED
- VRCS ±1 DEG DUTY CYCLES

- MAX TIP DISPLACEMENT (m)

PULSE AXIS	BEAM 1 +X	BEAM 1 −X	BEAM 1 +Z	BEAM 1 −Z
YAW	0.458	−0.458	0.027	−0.030
ROLL	0.195	−0.831	0.004	−0.045
PITCH	0.089	−0.096	0.032	−0.033

	BEAM 4 +X	BEAM 4 −X	DIFFERENCE +X	DIFFERENCE −X
YAW	0.458	−0.459	0.005	−0.005
ROLL	0.195	−0.231	0.001	−0.002
PITCH	0.092	−0.101	0.009	−0.009





- MAXIMUM LOADS

LOCATION	TYPE	MAX LOAD VALUE	MAX LOAD UNITS
BEAM ROOT	M (YAW)	699.0	Nm
	M (ROLL)	114.8	Nm
	V (X)	8.7	N
	V (Z)	0.9	N
	AXIAL	18.9	N
	TWIST	0.1	Nm
INTER BEAM	M (ROLL)	5.4	Nm
	V (Y)	2.7	N

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Using load maxima developed from the transient response analysis discussed on the previous chart, final beam internal loads were developed. Ultimate loads, including a 1.40 safety factor, were computed and are shown on the facing chart. The maximum inter-beam joint loads tabulated on the previous chart are also shown. Allowable loads were developed for each element, were compared with the maximum member loads, and margins of safety calculated. These are summarized for each element and the critical failure condition is also identified.

Margins are substantial for all elements but the beam posts. Their low margin results from local buckling of the one-edge free flat plate elements forming the flared sides of each post. Lips can be readily provided on the post sides and will increase the element buckling allowable significantly. They are also compatible with an alternative, potentially simpler, post feed clip in the beam builder.

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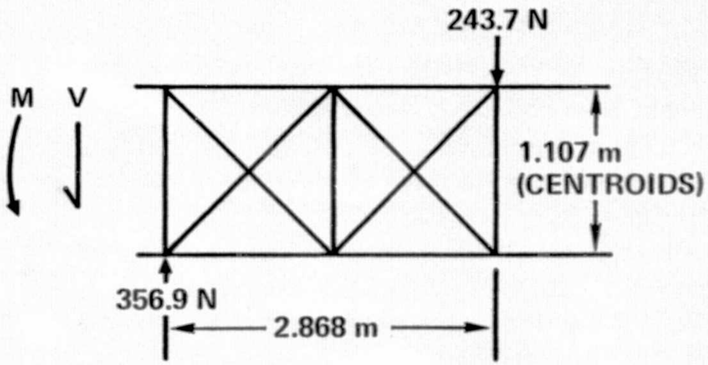
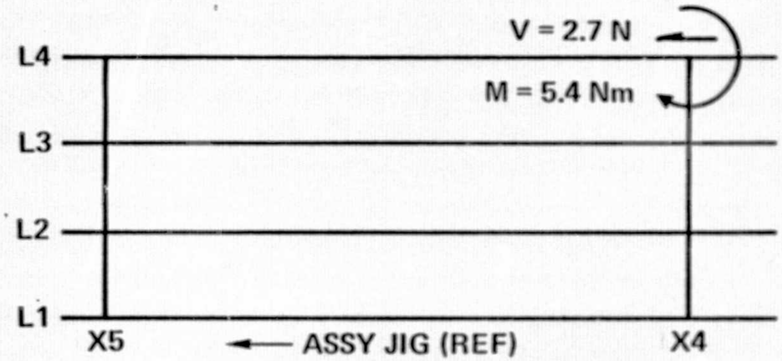
FINAL LOADS AND MARGINS

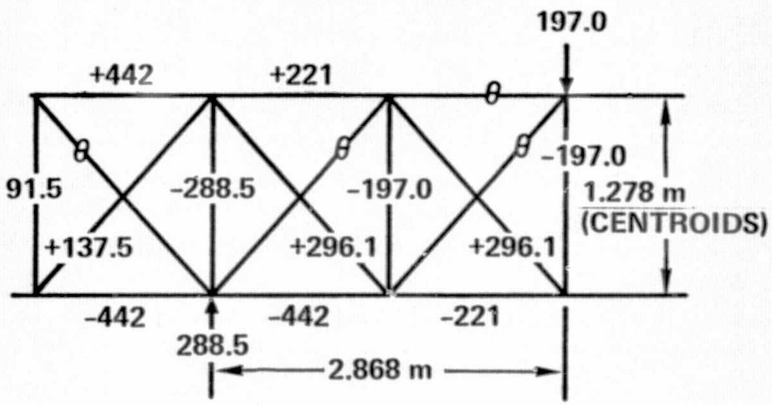
- **BEAM REACTIONS ON JIG**



- **INTER-BEAM JOINT LOADS**



- **INTERNAL LOADS IN BAY**



- **MARGINS OF SAFETY**

ELEMENT	M.S.	CONDITION
CAP	+ LARGE	COLUMN
POST	+ 0.09	LOCAL COM
CORD	+ 0.90	TENSION
LONG/CROSS BEAM JOINT	+ LARGE	SHEAR

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The position of the platform in free flight, the coordinate system and the sense of pitch, yaw, roll are as shown on the facing chart.

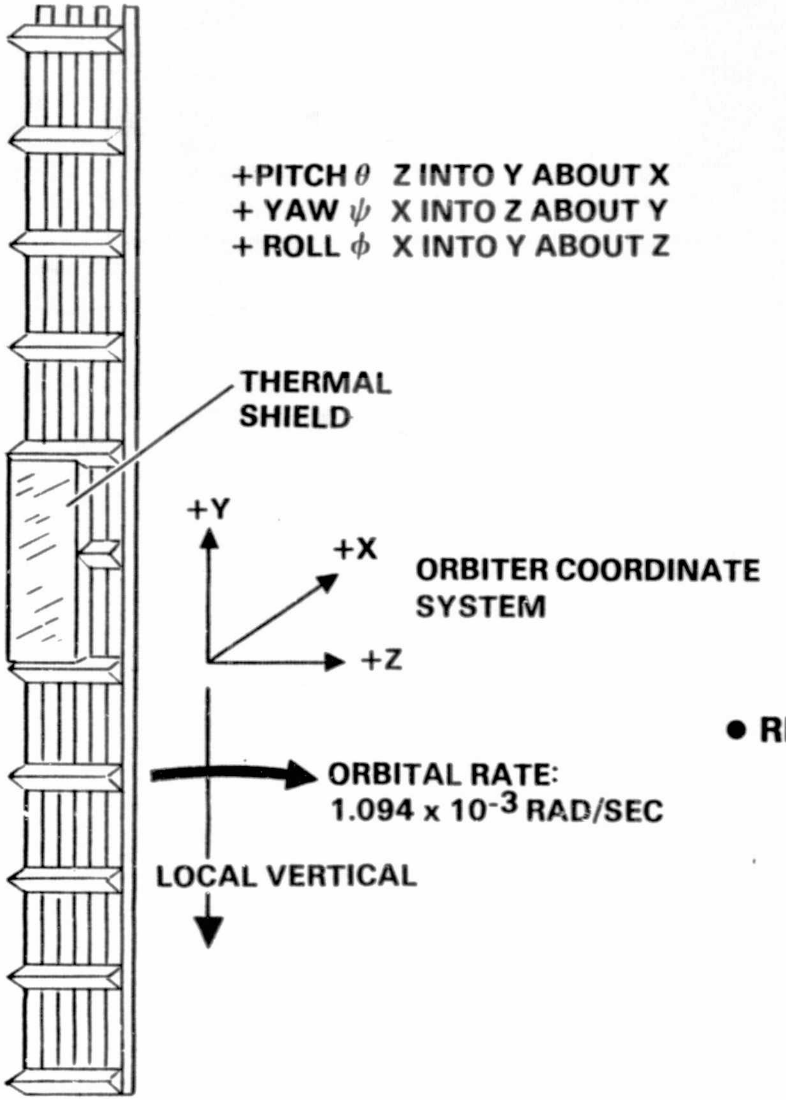
Analysis was conducted to determine the response of the free platform first bare, then with all platform systems installed. Environmental torques were computed about each axis for both platform configurations. Assuming initial rates of .01 degree/sec in each axis, the response to the essentially steady-state gravity gradient and gyroscopic torques was first determined. Oscillation frequency and amplitude and trim positions were determined. The effects of drag, solar, and magnetic torques were then computed for the bare platform.

These disturbance forces are cyclic in nature and except for yaw the frequencies are separated from the platform natural frequencies. The amplification factors in pitch and roll are 2.4 and 2 for disturbances at orbit frequency. In yaw the disturbance caused by drag will be cyclic due to the diurnal variation in atmospheric density. The amplification factor is 54.5 with a forcing function of ± 2.6 deg. The resulting oscillations would result in tumbling in yaw based on linear analysis.

However, platform release is planned with full systems installed. By properly positioning of the thermal shield with respect to the platform center of gravity the yaw stiffness can be increased. Because of the added stability in yaw provided by the thermal shield, the amplitudes will be within the capture range of the Orbiter during the 3 orbits the platform will be flying free. This assumes no damping, since the passive damping system has a time constant of 12 orbits. The resulting maximum response values are tabulated.

FREE PLATFORM STABILITY

- **RELEASE ORIENTATION**



- **APPROACH**
  - Evaluate bare platform & platform/equipment
  - Define environmental torques

    1. Gravity
    2. Gyroscopic
    3. Drag
    4. Solar
    5. Magnetic

    } { Roll, Pitch, Yaw }
  - Assume
    - Initial rates = 0.01 deg/sec
    - Damping = 0
  - Determine response
    - Oscillation frequency, amplitude, trim position

      -for-
    - Steady-state torques (1,2)
    - Cyclic torques (3,4,5)
- **RESULTS**
  - Bare platform $f_{yaw} \approx f_{orbit}$
  - Drag torque values at f_{orbit}
  - Bare platform tumbles in yaw
  - Aft-mounted thermal shield acts as "weather vane", increases f_{yaw}
  - Max response (deg):

    Roll + 5.11/-5.11

    Pitch +5.24/-5.68

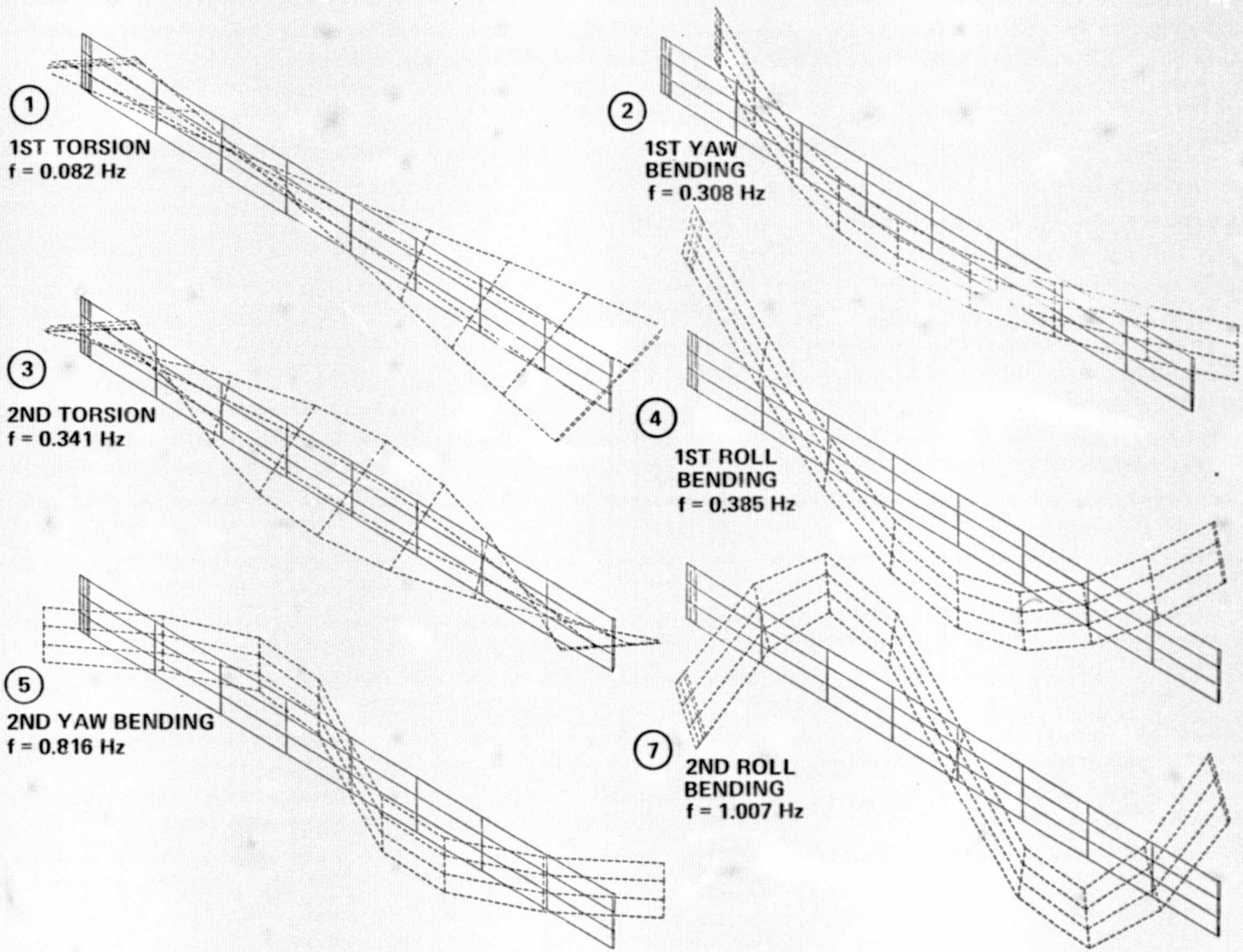
    Yaw +10.35/-5.99

01028082J0323

Mode shapes and frequencies were computed for the platform free of the Orbiter. The math model of the platform was extracted from the math model of the platform attached to the assembly jig and Orbiter. The mass used in the modal analysis was for a bare platform without instrumentation. Fourteen elastic modes were computed. The table below provides a list of the frequencies and a brief description of the predominate motion associated with each mode. Selected shapes of six free-free elastic modes are shown in the facing chart. Note that the first and second torsional mode parameters are very similar to the corresponding platform/Orbiter modes whereas bending frequencies are higher, as expected, for the free-free case vs. the near-cantilever Orbiter-attached case.

Mode No.	Frequency, Hz	Period, Sec	Description
1	.0815	12.2680	1st Torsion
2	.3081	3.2461	1st Yaw Bending
3	.3418	2.9255	2nd Torsion
4	.3854	2.5946	1st Roll Bending
5	.8160	1.2225	2nd Yaw Bending
6	.8325	1.2012	3rd Torsion
7	1.0068	.9933	2nd Roll Bending
8	1.5433	.6480	4th Torsion
9	1.5499	.6452	3rd Yaw Bending
10	2.2137	.4517	1st Longitudinal
11	2.4493	.4083	5th Torsion
12	2.4781	.4035	4th Yaw Bending
13	3.5207	.2840	6th Torsion
14	3.5719	.2800	5th Yaw Bending

FREE PLATFORM MODES



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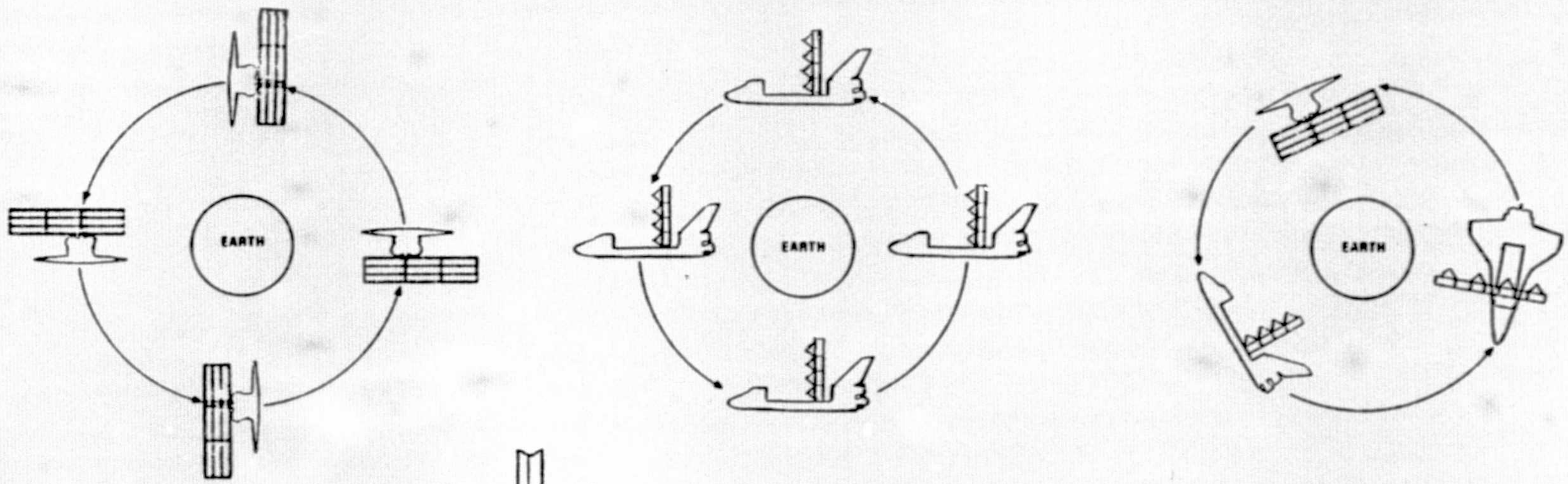
During SCAFEDS proposal preparation, various fabrication orientation options were developed and evaluated to support selection of a proposal baseline. At that time, the three candidate orientation families shown were evaluated with respect to their then-identified advantages/disadvantages.

The varying attitude option permitted optimized orientation for each mission phase but required low-rate orbiter maneuvers between successive positions. The inertially fixed option required omnidirectional communication capability and also experienced cyclic environmental torques. The earth-fixed option eliminated orbiter maneuvers, and minimized both the environmental torques and the consequent structural loads. However, within the Earth-fixed family, several options exist for orientation of system coordinate axes with respect to both the Earth and the orbit plane. The free-platform is stable if oriented in-plane with its long axis radial, and separation from the orbiter in that orientation is desirable. Consequently, a reference orientation satisfying this condition was selected at that time and was later adopted as the study baseline.

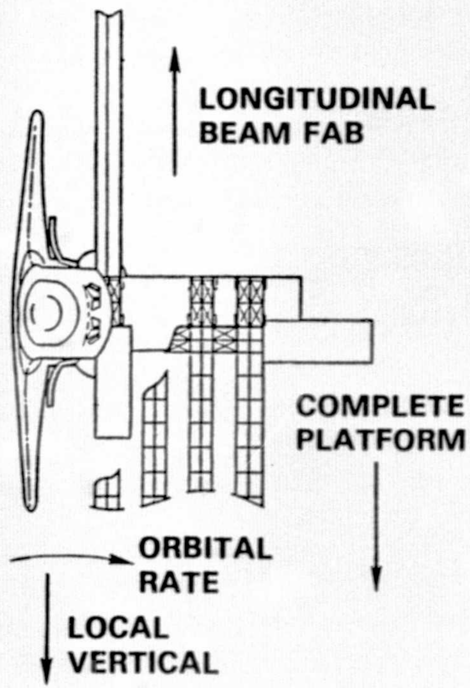
The final orientation selection required further system mass properties and stability/control analyses plus consideration of several other factors including viewing/illumination, potential thermal constraints on either the Orbiter or the platform, and communication capability. Results of these studies are discussed on the following charts.

FABRICATION ORIENTATION — I

- **OPTIONS**
  - **EARTH-FIXED**
  - **INERTIALLY FIXED**
  - **VARYING**



- **INITIAL BASELINE**



- **CONSIDERATIONS EVALUATED**
  - Mass properties
  - Stability & control
  - Induced loads
  - Communications
  - Viewing&illumination
  - Thermal effects

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At any mission time the Orbiter/platform system will exhibit a discrete set of inertias and will remain stable if its principal axes are oriented as shown.

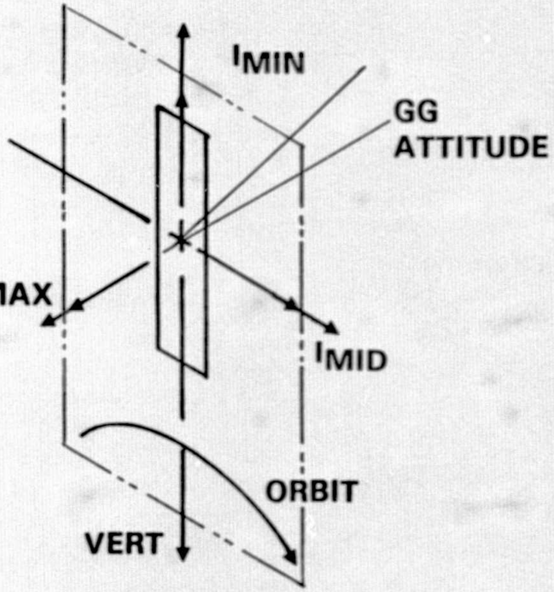
Throughout the mission sequence, significant inertia changes occur about the roll (X) and yaw (Z) axes such that the stable attitude changes with mission event. Therefore, it was necessary to reconsider the varying-attitude option as a possible orientation candidate. To operate in this mode required attitude control maneuvers to realign the system as the principal inertia relationships changed, but presumably permitted the VRCS to operate in a rate damping mode once the stable gravity gradient attitude was achieved. This was expected to result in reduced propellant consumption and low beam/platform structural response due to the long periods of widely spaced very-short duration firings characteristic of rate mode operation. Stability and Control analyses were conducted to determine system characteristics and these indicated that closed loop attitude control was still necessary about certain axes. Also, mass properties data showed that none of the successive gravity gradient orientations would result in platform orientation in the desired post-separation stable position without further attitude control maneuvering. Consequently the anticipated propellant consumption and dynamic response advantages were challenged.

Stability/Control analyses were also conducted on the baseline orientation. Examination of the resulting phase plane plots indicated that the system exhibited a stable oscillation about both the yaw and roll (highest inertia) axes within $\pm 10°$ attitude error limits. Consequently, the system could be operated in a rate damping mode about two axes with closed loop attitude control required only in pitch. The resulting attitude excursions and periods are shown. Since no specific attitude error limit has yet been identified, the baseline orientation is preferred from a stability/control point of view.

FABRICATION ORIENTATION — II

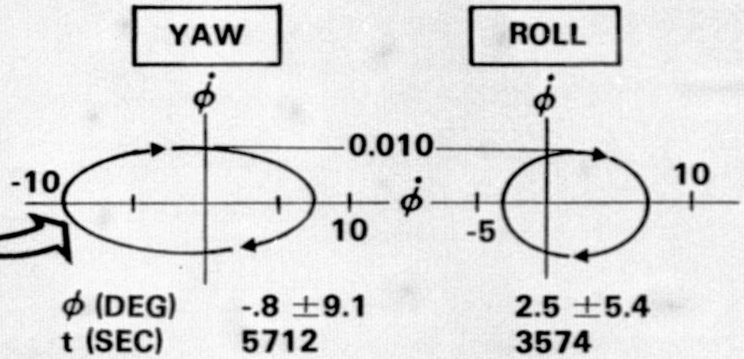
MASS PROPERTIES CONSIDERATIONS

- Gravity gradient attitude varies (inertia cross-overs)
- System GG attitude
- Free platform GG attitude



STABILITY & CONTROL CONSIDERATIONS

- Varying GG option
  - Maneuvers required
  - Closed-loop attitude control required
  - No RCS or dynamic response advantages
- Constant, earth-fixed option
  - Platform in release attitude
  - No maneuvers
  - No known error limits
  - Rate mode operation okay in yaw, roll
  - Closed-loop pitch control: $\phi = \pm 5.0$ deg, $t = 2736$ sec
  - Preferred option



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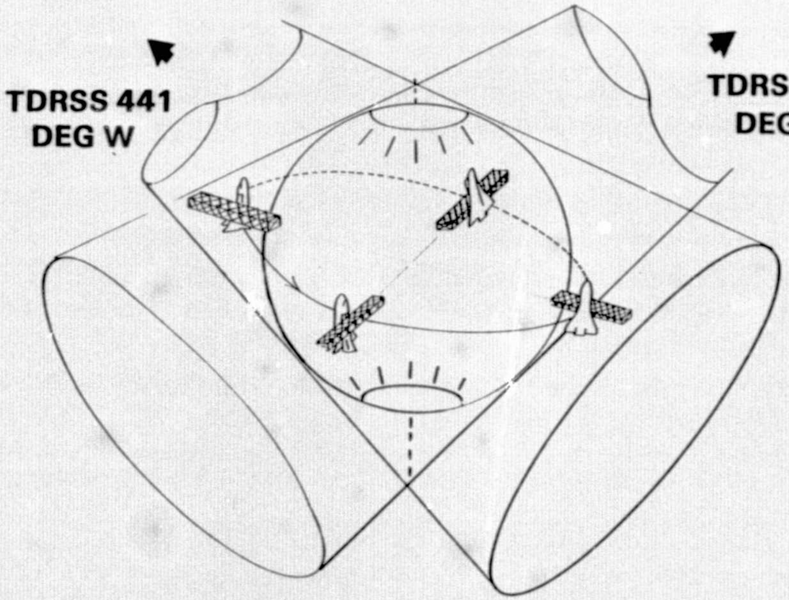
SCAFE communications requirements were examined for impacts affecting the orbiter/beam fabrication and assembly operations. The results indicate that SCAFE/Orbiter RF communication operations will have no major impact on SCAFE fabrication and test operations. The antenna coverage the orbiter will have with TDRSS is shown on the facing page. Ku-band coverage with the steerable disk on the port side of the orbiter is blocked by the orbiter body over a 70° arc centered about the TDRSS "no coverage zone", and for a short period when the large beam structure interfers with the antenna beacon. Analysis also indicates that the addition of a similar steerable Ku-band antenna on the starboard side of the orbiter would reduce the no coverage area about the TDRSS "no coverage zone" to 18°.

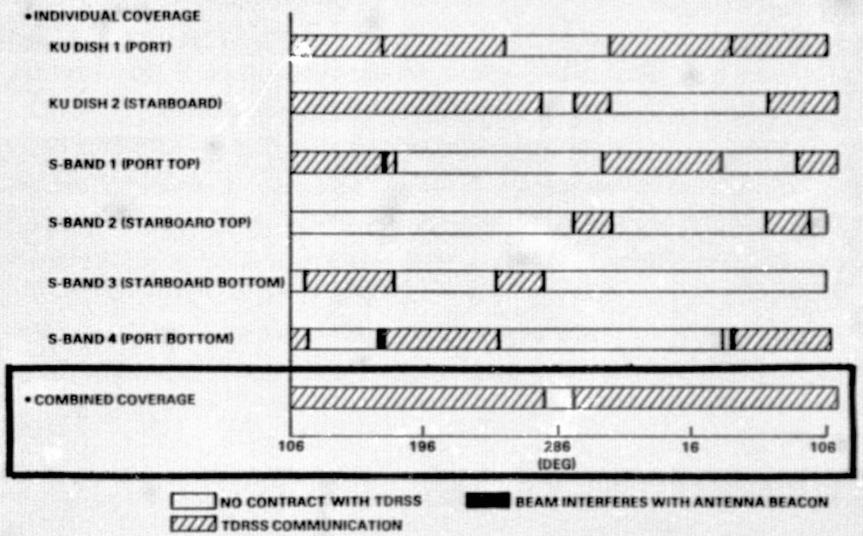
TDRSS coverage with the four orbiter S-band antennas, which are located on the 45° bisectors of the orbiter pitch and yaw axes, can be achieved except over an 18° arc centered about the TDRSS "no coverage zone". The antennas must be switched at least six times during an orbit, however, since the coverage of each antenna is broken up into several regions.

FABRICATINON ORIENTATION - III

- **COMMUNICATIONS CONSIDERATIONS**



ANTENNA COVERAGE FOR ORBITER-TDRSS LINK



RESULTS

- **70 deg no coverage zone using port side ku-band antenna**
- **18 deg no coverage zone using port & starboard antennas**
- **18 deg no coverage zone using switched s-band antennas**

CONCLUSION

- **No significant SCAFE impacts - combined coverage of 342°**

The principal viewing/illumination requirement is that the selected orientation minimize platform back lighting, by either direct or Earth-reflected sunlight, since this severely impairs direct viewing from the aft facing cabin windows. Consequently, orientations in which the Orbiter +X (aft) axis points toward either the Sun or the Earth should be avoided. Since the mission orbit has a low inclination with respect to the ecliptic ($\sim 20°$) this can be achieved by orienting the Orbiter longitudinal (X) axis essentially normal to the orbit plane. This condition is provided by the baseline orientation. However, an alternative orientation, in which the Orbiter leads the platform along the flight path also satisfies this requirement.

From the previous chart the yaw oscillation is $-.8° \pm 9.1°$. This results in a slight sunward viewing component (9.9° max) from the aft cabin windows. However, the corresponding roll oscillation has a 1° bias, due to drag effects, favoring the reference orientation. Although no strong discriminator exists between the two, the baseline orientation is preferred for viewing/illumination.

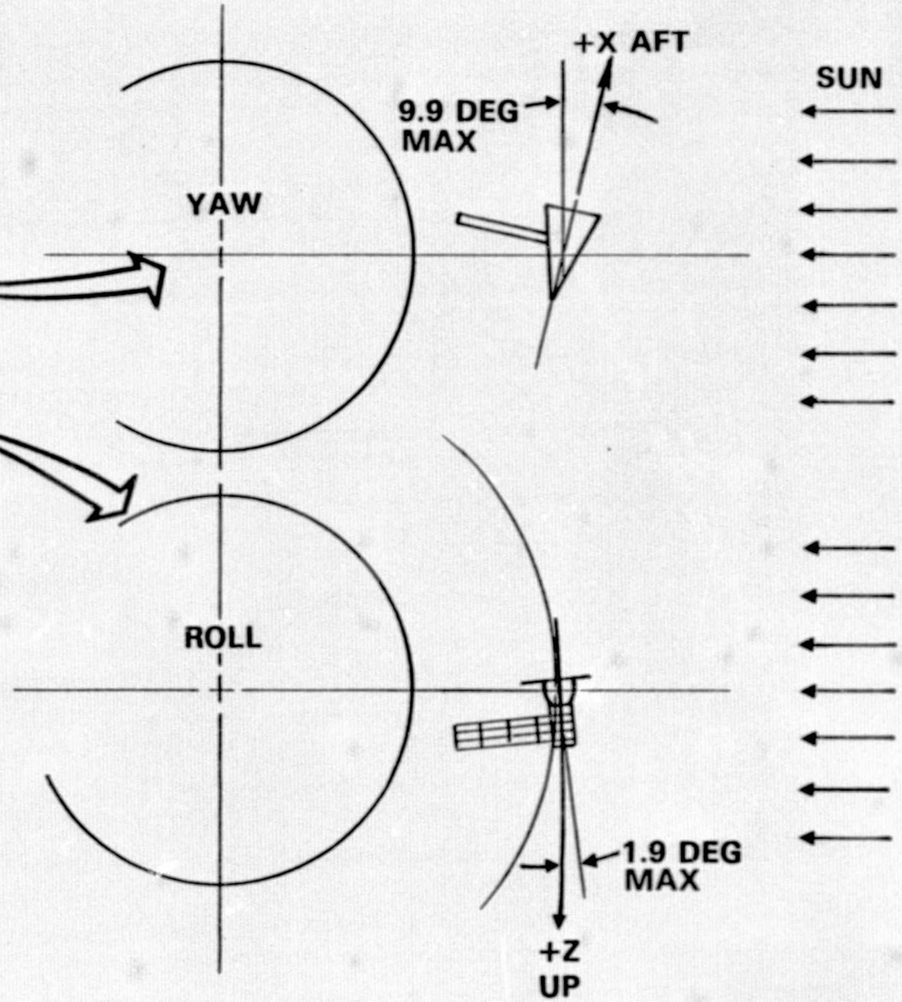
Space heating analyses conducted for the baseline orientation indicate very small structural distortion and relatively small temperature excursions, with peaks well within the maximum use temperature for the composite structural materials. Consequently there are no thermal constraints on platform orientation.

Furthermore, the Orbiter is required (per JSC07700) to permit sustained freedom of orientation, including continued full sun normal to the radiators, for orbit inclinations less than 55°. Since the baseline SCAFE orbit inclination is 28.5°, there is also no thermal constraint on Orbiter orientation. The reference orientation is therefore satisfactory in terms of thermal considerations.

As a result of the considerations presented on this and the preceding charts the baseline Earth-fixed orientation is preferred and is recommended for adoption in subsequent program effort.

FABRICATION ORIENTATION — IV

- **VIEWING & ILLUMINATION CONSIDERATIONS**
  - Platform backlighting bad
  - Prefer minimum earthward & sunward viewing component through aft cabin windows
  - Baseline orientation good
  - Slight roll drag bias favors platform leading orbiter
- **THERMAL CONSIDERATIONS**
  - Platform insensitive: distortion & load negligible
  - No orbiter constraints for orbit i $<$ 55 deg
- **CONCLUSION**



Baseline earth-fixed orientation preferred

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PART II FINAL REVIEW

INTRODUCTION

Overview

FLIGHT EXPERIMENT INTEGRATION

Requirements & operations
Tests & experiments
EVA/IVA
Future applications

SYSTEM DESIGN & ANALYSIS

Fabrication systems
On-orbit environment & behavior

PROGRAMMATICS

Development plan & cost

STUDY SUMMARY

Conclusions
Recommendations

A master development plan schedule has been generated for a launch date in mid-1982, as stated in the study ground rules, and driven by the Engineering Development and Qualification Test requirements delineated below. The program can be accomplished with a minimum of risk to meet the scheduled launch date.

Schedule and durations are based on the following guidelines and assumptions:

1. Follow-on SCAFE contract ending 1 Oct 1978.

2. Source selection is an estimate of time to bid and select the Phase B contractor. The Phase B contractor is assumed to be selected to conduct the following development phase (Phase C/D) without a competitive bid.

3. Follow-on contract produces the following products (as a minimum):
   a. Updated conceptual design of SCAFE
   b. Preliminary specification for beam builder and assembly jig subsystems
   c. Plans and costs for Phase B

4. Phase B study produces the following products (as a minimum):
   a. Requirements in the form of specifications
   b. Definition of flight experiments
   c. A selected system predesign
   d. Plans and costs for development

5. Included in Phase B is a prototype development program to be carried out before the start of C/D on the subsystems for the beam builder and assembly jig.

6. Phase C/D system engineering and integration includes definition of the integrated payload system and compatibilities with the STS, mission and flight operations, verification, software integration, reliability and safety analyses, and configuration management.

7. Phase C/D design and analysis task is expected to reflect maximum utilization of existing equipment listed in the NASA Low Cost Program Office CASH catalog, as well as multi-use mission spacecraft equipment.

8. Phase C/D prototype development equipment will be as near to final design as practical including drives, controls, and sensors.

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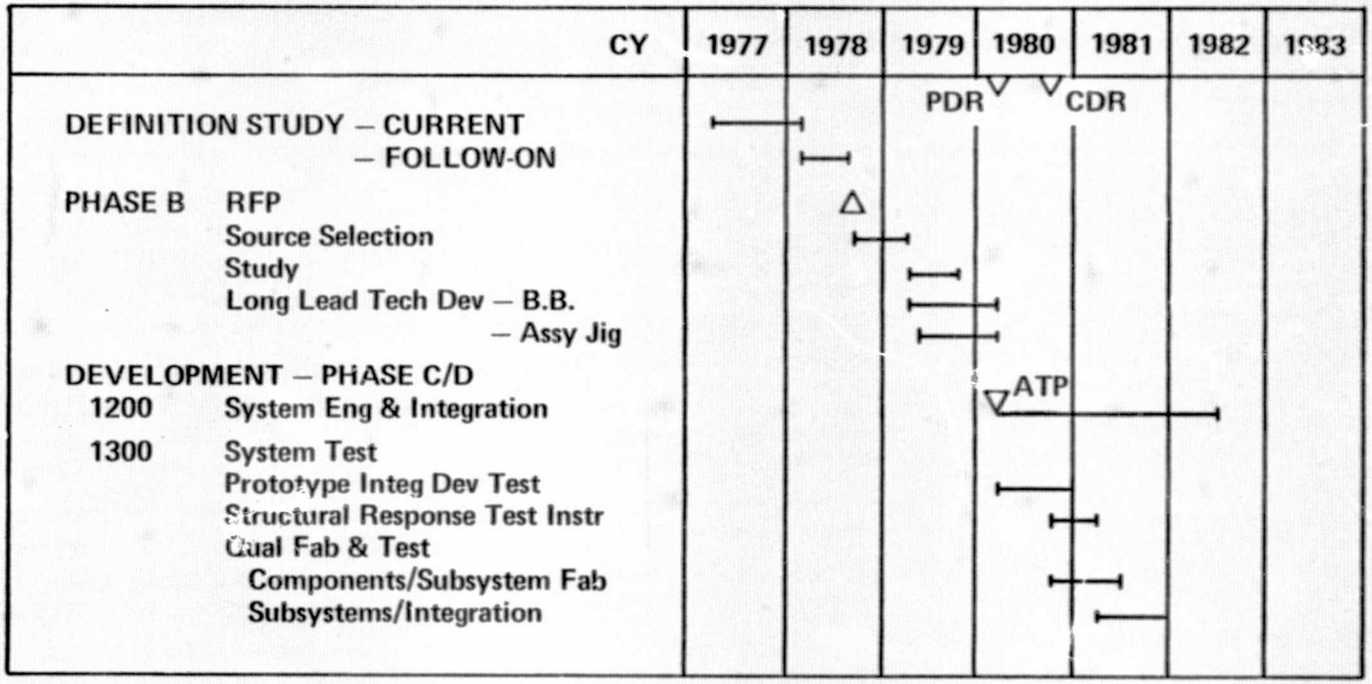
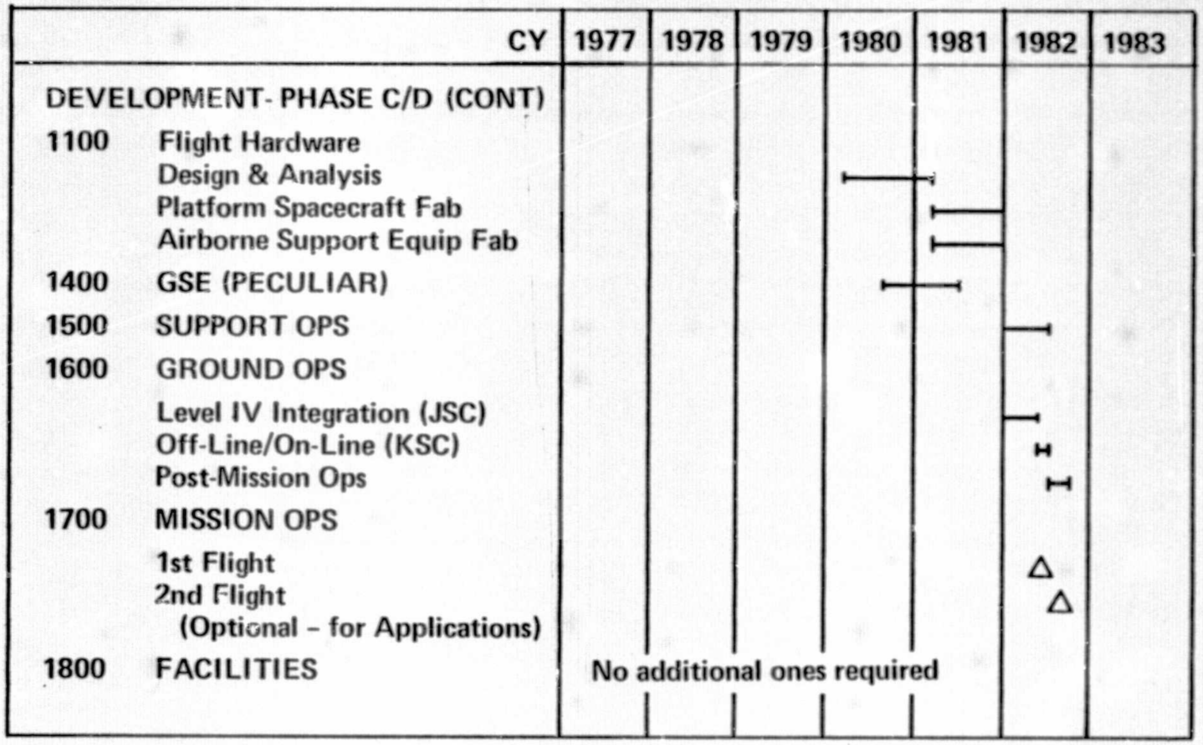
PRELIMINARY SCAFE PROGRAM DEVELOPMENT SCHEDULE



*Post separation experiments instrumentation assumed to be GFE & not assumed in this schedule.

PRELIMINARY SCAFE PROGRAM DEVELOPMENT SCHEDULE



This chart indicates the recommended approach, activities and schedule to be accomplished before the start of Phase C/D in subsystem development for the beam builder in order to meet the mid-1982 launch date which was ground ruled for this study.

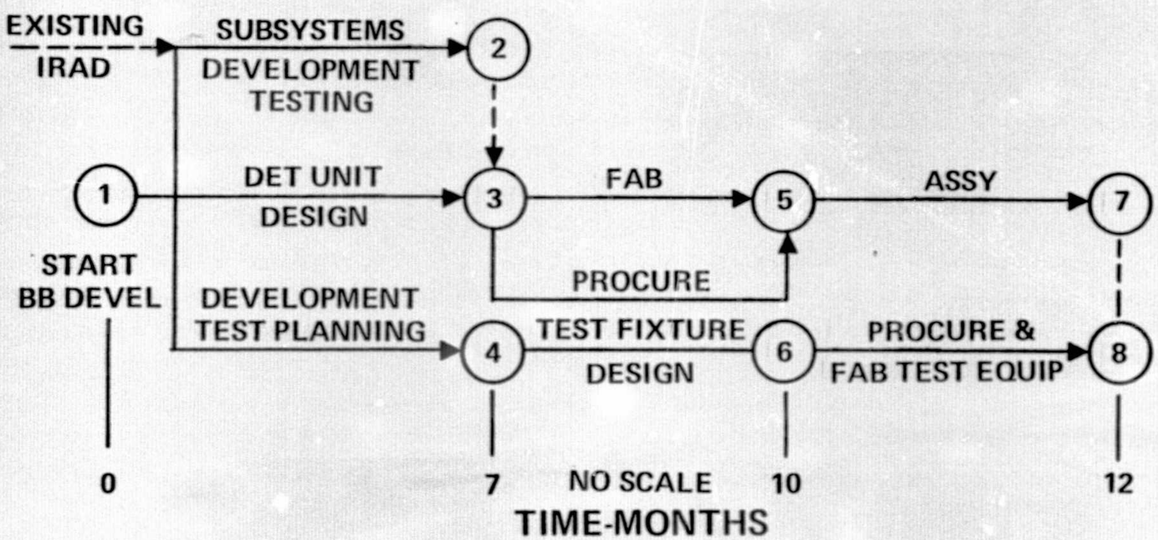
These subsystems will be prototypes of the flight hardware and will be integrated, after individual development testing, and ready to be tested as an integral assembly at the start of Phase C/D.

LONG LEAD TECHNICAL DEVELOPMENT

Beam Builder

RECOMMENDED APPROACH

1. Develop separately
   - Welding Subsystem
   - Heating subsystem
   - Cap-forming machine (in work)
   - Cut-off subsystem
   - Storage canister
2. Develop cord applicator subsystem & cross-member subsystem as part of beam builder DET unit development



DET = Design/Evaluation/Test

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This chart indicates the recommended approach, activities, and schedule to be accomplished before the start of Phase C/D in subsystem development for the assembly jig in order to meet the mid-1982 launch date which was ground ruled for this study.

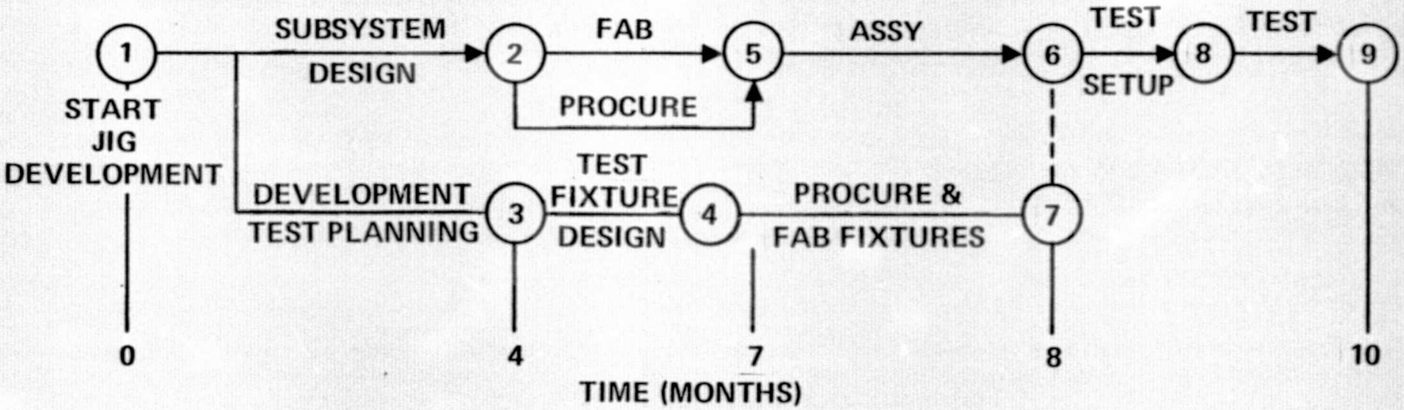
A mock-up of the assembly jig will be developed to proof out and develop the general arrangement.

These subsystems will be prototypes of the flight hardware and will be ready for testing integrated testing at the start of Phase C/D.

LONG LEAD TECHNICAL DEVELOPMENT
Assembly Jig

RECOMMENDED APPROACH

1. Develop jig mock-up to proof-out & develop the general arrangement
2. Develop separately for DET
   - Single longitudinal beam handling subsystem
   - Platform welding subsystem
   - EVA bridge mechanism



DET = Design/Evaluation/Test

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The initial work breakdown structure (WBS) for the SCAFE program is shown on the facing chart. It serves to identify all of the cost elements included in the cost analysis task. This WBS contains all of the hardware and tasks associated with program development and test, the fabrication of the flight hardware, and the operations activities incurred during the first flight. It is assumed that the Shuttle user charge includes all Shuttle related activities such as on-line payload installation (OPF), MOC activities, flight crew costs and other common ground operations/mission operations and activities. Other Shuttle related services such as OMS kits, RMS, and other optimal services are added to the Shuttle user charge for the basic transportation. Potential user charges for tracking and data acquisition (TDRSS, etc.) are carried as separate program level items.

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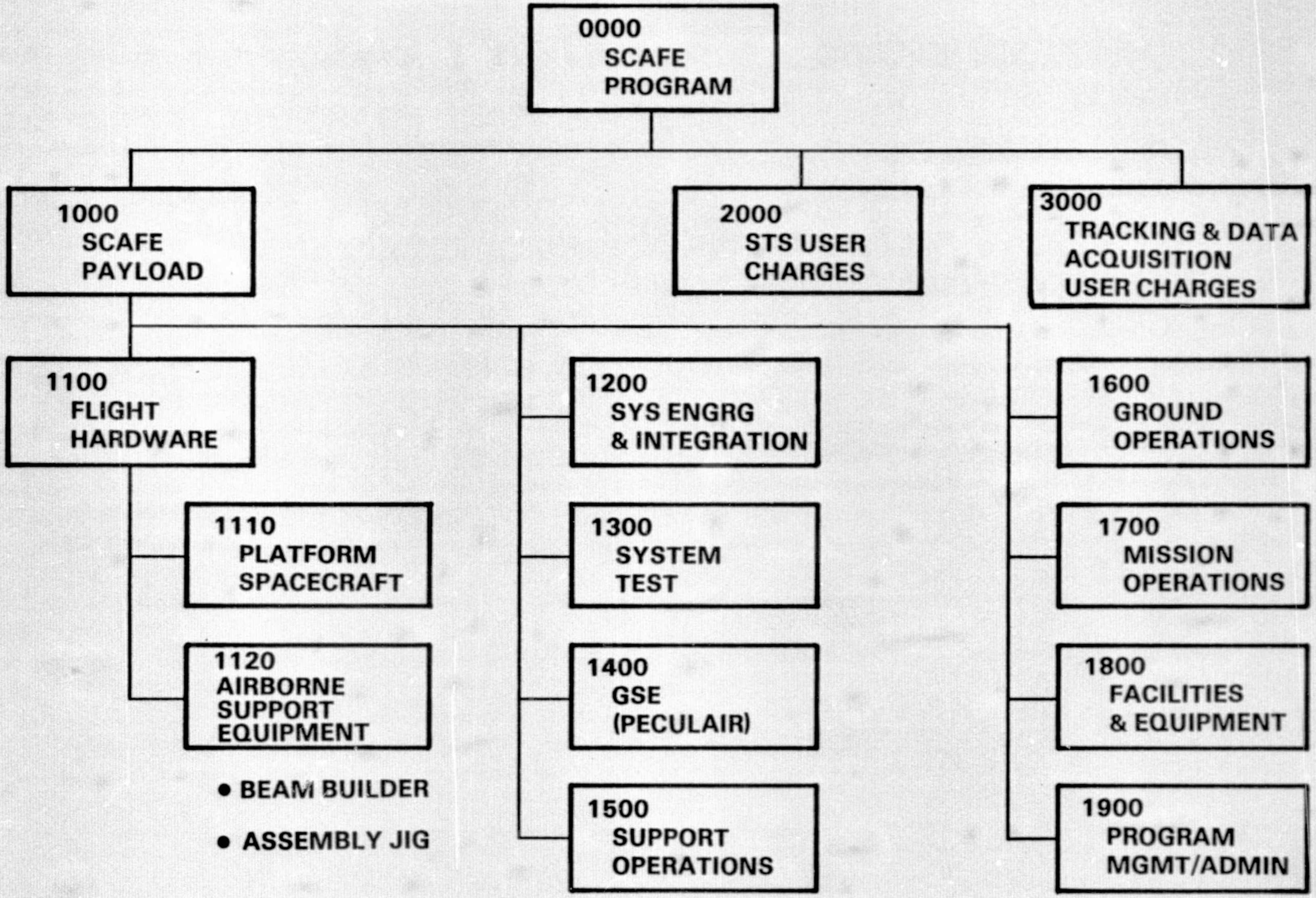
WORK BREAKDOWN STRUCTURE



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A cost analysis of the SCAFE Program has been conducted and detailed data collected per the WBS on the preceding chart.

Summary data is shown for Pre-phase C/D prototype development effort in addition to Phase C/D costs and Shuttle user charges.

Phase C/D cost totals are presented for the nonrecurring (development), the recurring production (flight hardware), and recurring operations phases of the program. All costs are estimated in current constant FY 1977 dollars and prime contractor fee is not included. The estimate includes all payload incurred costs through the first launch (1982) of the fabrication experiment including three months of experiment orbital monitoring and data acquisition.

The nonrecurring development or DDT&E phase includes all of the one-time tasks and hardware to design and test the SCAFE experiment. The production phase (unit cost estimate) includes all tasks and hardware necessary to fabricate one complete set of flight hardware equipment. The operations phase includes all preparation launch and on-orbit operations associated with the SCAFE experiment.

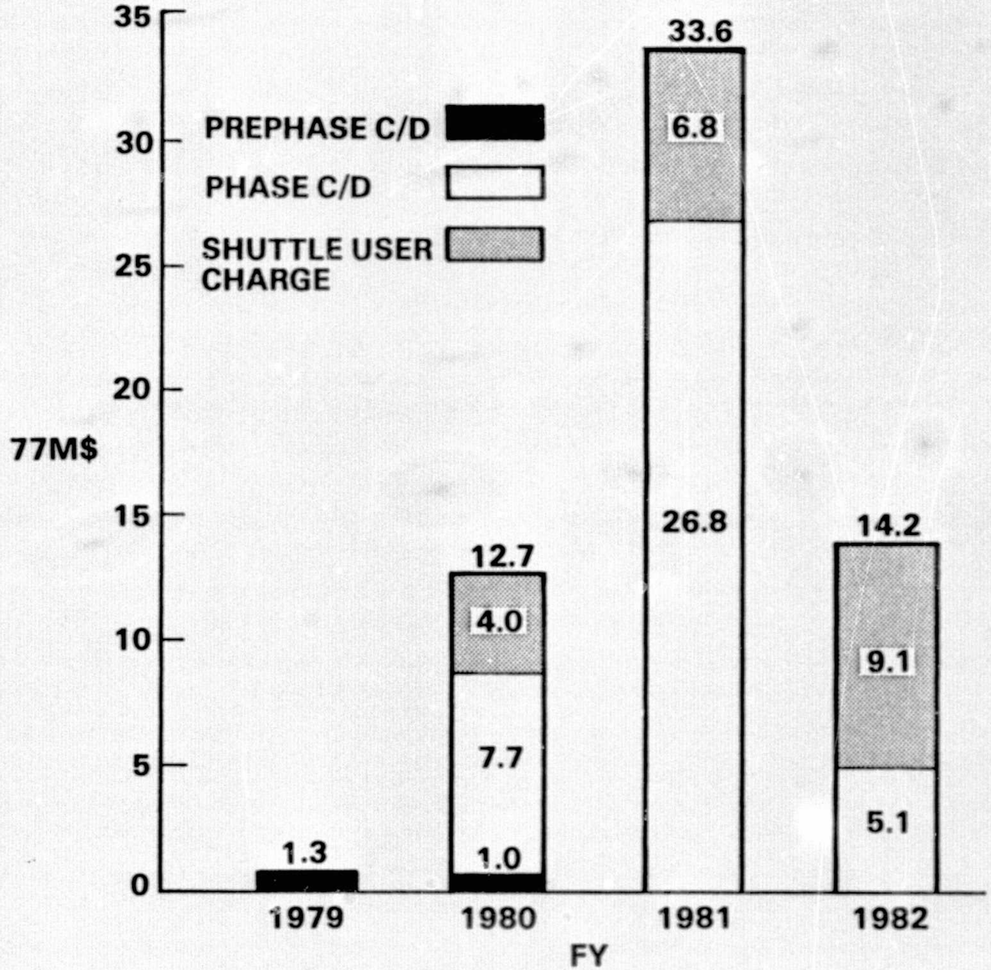
The annual funding requirements for the SCAFE program are also shown. This distribution was established by spreading individual cost elements in accordance with the program schedule shown previously. Shuttle funding was spread in accordance with the Space Transportation System User Handbook, dated June 1977.

FUNDING REQUIREMENTS

• **COST SUMMARY ($M)**

PREPHASE C/D	2.30
PHASE C/D	
NONRECURRING	33.39
RECURRING	
PRODUCTION	4.71
OPERATIONS	1.50
SCAFE PAYLOAD	41.90
USER CHARGES	
SHUTTLE	19.89
TRACKING & DATA	(TBD)
SCAFE PROGRAM	61.79

• **ANNUAL FUNDING**



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PART II FINAL REVIEW

INTRODUCTION

Overview

FLIGHT EXPERIMENT INTEGRATION

Requirements & operations
Tests & experiments
EVA/IVA
Future applications

SYSTEM DESIGN & ANALYSIS

Fabrication systems
On-orbit environment & behavior

PROGRAMMATICS

Development plan & cost

STUDY SUMMARY

Conclusions
Recommendations

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Principal study conclusions are grouped by major category and are presented on the following two charts.

CONCLUSIONS — I

- **SYSTEM DESIGN & ANALYSIS**
  - Fabrication equipment
    - Automated fabrication & assembly feasible
    - Electromechanical devices state-of-the-art but continued development needed in selected areas
    - Control functions within memory & speed capability of current microcomputer systems
    - Power requirements well within orbiter capability
    - Control & monitor concepts compatible with orbiter crew/equipment
    - Orbiter software support functions generally acceptable
  - Platform
    - Compatible with fabrication equipment capabilities
    - Accommodates baseline mission but final configuration requires better definition of application
    - Hybrid laminate material minimizes forming energy; has high E; low CTE; uses low-cost pitch fiber
    - Dynamic response & resulting structural loads low
    - Peak temperatures low & orbital variation small
    - Thermal distortions/loads low
    - Open section cap easy to form, exhibits large M.S.

CONCLUSIONS — II

- **FLIGHT MISSION INTEGRATION**
  - All objectives accomplished in single 7-day mission
  - Fabrication & assembly fully automated; EVA capability devoted to equipment installation & checkout, maintenance demo
  - System orbiter compatible: weight & cg; support reactions; VRCS control; low propellant consumption; low power demand; no radiator interface
  - Constant earth fixed orientation preferred: platform in release position; rate mode control in yaw, roll

- **PROGRAMMATICS**
  - Mid-1982 flight date achievable if:
    - Prototype fabricate equipment development parallels ϕB
    - ϕC/D not re-competed
  - Total SCAFE payload cost $41.9M
  - Single mission accomplishment saves $19.9M Flight 2 user charge

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As a result of effort to date on the present SCAFED Study, several areas of further activity have been identified. The most significant of these have been collected into suggested follow-on task groups and are presented on the following two charts.

RECOMMENDATIONS — I

- DEVELOP/DEFINE PLATFORM APPLICATIONS
  - Screen potential applications, select candidates
  - Develop configuration & mission operations requirements
  - Select preferred application; prepare detailed design; conduct supporting analyses
  - Integrate into flight mission: evaluate orbiter compatibility; define mission operations & flight operations constraints
- FURTHER DEFINE SCAFE STRUCTURE & FABRICATION SYSTEM CONCEPTS
  - Conduct selected analysis/design/Orbiter interface trades
  - Update beam builder & assembly jig concept designs
- DEFINE GROUND-BASED BEAM BUILDER DEVELOPMENT ARTICLE
  - Prepare detailed concept design
  - Define a development test plan
- MANUFACTURE & TEST
  - Develop & fabricate equipment prototypes; conduct sequenced tests with prototype controller
  - Continue materials characterization
  - Conduct component & assembled beam tests

RECOMMENDATIONS — II

- **UPDATE PROGRAM DEFINITION**
  - Define & integrate latest requirements: selected application(s); updated structure & fabrication system concepts; ground-based beam builder; manufacturing & test
  - Conduct programmatic schedule & cost trades
  - Prepare development plan; conduct cost analysis

- **ALTERNATIVE BEAM CONCEPT**
  - Develop methods & conduct detailed analyses
  - Perform detailed design studies; support with test data
  - Trade automatic fabrication concepts; select preferred concept; prepare concept design

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